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A Review."

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1 Introduction

The concept of business process management (BPM) aims to integrate distinct process domains amongst an organization. Distinction thereby is given both, vertically and horicontally. Vertically, technical and formal layers describe processes via cascading abstraction granularity. At the business sphere, process' - also due to their dynamic characteristic - often are loosely described e.g. by manuals written in natural language. Languages on that level are characterized by domain specific terminology as cost accounting or legal and are ideally but not given aligned globally / organizationally. On narrow, IT driven levels, tautologically stricter formalism is required in order to ensure machine and process ability. In order to intertwine the two sides various approaches are applied, as semiformal, graphical modeling languages that are machine readable, but easy readable for non-IT experts too.

The 'horizontal' challenge is, that large or acquisitioning organizations, face heterogeneity amongst branches and legal entities. Domain specific terminology and underlying process models are likely to distinct even by analogue domains due to given, mature systems. In consequence a standardized, IT funded, globally semantic valid and integrated business process management is desired. Various researchers analyzed this problem, e.g. Herbst and Karagiannis (1998), Leymann, Roller, and Schmidt (2002) and Hepp, Leymann, Domingue, Wahler, and Fensel (2005). Distinct focal aspects, are thereby raised as lack of (semantic) visualization (Fill 2009) and lack of an appropriate formal semantic representation of company's process space Wetzstein et al. (2007). Out of conceptual, modeling perspective, aim is deduction of this fussiness by semantic integration, as global valid systems, newly set up from scratch, are cost intensive. Therefore, primary claim is to close 'the gap' between heterogenous IT and business environment semantically.

Whereas the 'gap' itself is diagnosed twofold: as lack of automation in case of process updates or outliers: First, IT processes are claimed to react automatically and 'intelligent', neglecting human intervention. Second, business process management aims to align and steer processes globally, just to overcome domain heterogeneity.

Aim of this work is to examine distinct approaches and provide insight on approaches scholars have provided since 2005. In the first sections introduction on the a) BPM concept, b) process models and c) semantic web technologies is provided. These three stacks are constitutional and impact semantically integrated BPM conceptually as well as technologically. Subsequently literature concerning semantic BPM will be elaborated and discussed.

Since this work is written by a student with economy background, focus is put on business relevant topic. Clustering, as ‘quality assurance’ is driven by business interests.

2 Definitions

In the following abstracts an overview on definitions and terminology is provided.

Artefact: represents a distinct component considered as modeling subject. E.g. specific business entity.

Concept: refers for this work to an abstracted, simplified view on issues that is represented by elements such as artefacts and is driven by certain purpose.

Integration: in regard of semantic business process management can be described as intertwining determinant, existing, heterogenous process models, against the background of linking corresponding meta models and its elements, to gain transcend business process semantics. Thereby, the task of ‘intertwining’ is to find a bipolar processing and understanding. ‘Determinant, existing, heterogenous process models’ refers to the axiom of diverse process models. The background of linking corresponding meta models and its elements, refers to the requirement of bipolar processable representation. The task of integration is described by Karagiannis (2007) of bringing “together different existing “artefacts” of potentially various kinds. These artefacts are most often created corresponding to different modeling languages and, therefore, metamodels.” Subsequently “translation layer” are required “that allows for the mapping of language elements and, thus, model elements” (Karagiannis, 2007).

Metamodel: consists out of the prefix meta that refers to ‘upper’. Combined with ‘model’ it hints on a model above the “original”, that schematically and fragmented describes information. Reference models, that is mentioned within the literature corpus too, refer by differentiation to a model that exemplifies. The main usages are described twofold: “On the one hand it is applied for design purposes and on the other hand to solve integration problems” (Karagiannis & Höfferer, 2006).

Purpose is to overcome the heterogeneities of resources – regardless if they are data, information systems, or anything else – they have to be represented in an adequate way.”(Höfferer, 2007). (Sub-) Types of meta models are meta data models and meta process models.

Method: Composition of language or language-based meta model and process-based procedure. Sometimes also referred to ‘technique’ that describes, based on a rule system, procedures to achieve (scientific) rationale.

Methodology: Combined term of method and logic. Drill down of software engineering into phases and steps. It mostly consists out of upfront specified tasks and sequences. Phases are repeatedly compared with a life cycle approach.

Modeling Language: “A modeling language is any artificial language that can be used to express information or knowledge or systems in a structure that is defined by a consistent set of rules. The rules are used for interpretation of the meaning of components in the structure.” (Höfferer, 2007). A modeling language is founded by syntax, semantics and notation (Karagiannis & Kühn, 2002). Broken down it consist of

- Graphical modeling languages
- Textual modeling languages
- Algebraic modeling languages
- Behavioral and discipline specific
- Framework and domain specific

‘Modeling method’ and ‘modeling language’ are partially used synonymously in scientific literature. Being precise, modelling method is considered to be a “more abstract term in comparison to a modelling language, given the fact that a modelling language is one of the necessary parts of the modelling method” (Lekaditis 2014).

Modeling procedure: “The modeling procedure is defined by steps and results. These criteria describe, how the user actually builds models, i.e. the sequence of actions performed by the modeler in order to create valid models.”(Bork & Karagiannis, 2014). Defines how constructs have to be combined in order to create a valid model (Höfferer, 2007).

Notation: Refers to visualization of modeling languages with subordinates 'static' and 'dynamic'. The letter considers the model state by differing the notion between representation and control.

Ontology: Refers to vocabulary or documents in specific format, that describes relationships between objects such as concepts, data or artefacts. It further combines representation, denomination and definition of categories and properties.

As out of a first glance ontology and meta model do overlap, a precise distinction amongst their relationship has to be ensured: Ontologies aim to express information out of a domain by "utilizing a grammar for using vocabulary. The grammar specifies what it means to be a well-formed statement, query, etc." whereas meta models are described as "explicit description of how a domain-specific model is built. This comprises a formalized specification of domain notations and a strict rule set" ("The Web Graph Database," 2018). This leads to the fact, that a "valid metamodel is an ontology, but not all ontologies are modeled explicitly as metamodels".

Process Modell: Purposeful, based on particular taxonomy, mapping of a process in explicit specifications. Time and content logical sequencing are the founding structure. Purposes vary from analysis to execution. Insofar, "process model contains tasks and associated coordination constraints to control scheduling and execution. Model elements include activities and logical elements among the activities." (Wang et al., 2011).

Explicit specifications are to "abstract definitions or executable specifications; they may be expressed in a declarative or procedural style" (Filipowska, Hepp, Kaczmarek, & Markovic, 2009). Functionality, mean and dependency are core dimensions. Process models "usually come from past modeling done by humans, software packages in use, or be brought in as requirements from outside the enterprise" (Hepp & Roman, 2007).

Process: is the purposeful sequencing of tasks, driven by goals. Definition by (Hepp et al., 2005): "… chains of activities that are actually executed, e.g. explicitly designed processes as well as ad hoc processes."

Semantics: out of Greek and is translated to 'meaning model'. For the purpose of this work, semantics refer to meaning that is to be generated and virtualized. Literature distincts by:

Structural Semantics: is the relationship between meanings of terms and deals with the set-up of meaning along subordinated terms. Thus, a preconditioned assumption of structural semantics is inner arrangement. It can be informally described by using natural language (Bork & Fill, 2014). Further breakdown differs between type and inherent semantics.

Type Semantics: is usually defined with the meta model of a modeling method by providing semantics for each model element (i.e. type) on a meta level (Bork & Fill, 2014).

Inherent Semantics: Inherent semantics describes the semantics of concrete instances of the meta model elements (i.e. concrete instances in the model) (Bork & Fill, 2014). Type and inherent semantics are exemplified by (Höfferer, 2007). Firstly, type semantics:

".... student is derived from the metamodel construct entity and therefore is a kind of real world object and not a relationship. But in this context, we are not able to state anything about the semantics of student itself. It can by no means be reasoned that this term denotes a human person that can be male or female and who is attending an university-like institution."

and inherent semantics:

"... in this context we are not able to state anything about the semantics of student itself. It can by no means be reasoned that this term denotes a human person that can be male or female and who is attending an university-like institution. We would like to call this information inherent semantics as it describes a kind of "inner meaning" of modeled resources that is exceeding the type semantics that is being inherited by the elements of the metamodel-layer."

Behavioral Semantics: Behavioral semantics abstracts from implementation details and allows to describe the behavior of software components in a representation-independent way. This semantics "describe the degree of formalization according to the process model execution" (Bork & Fill, 2014).

Semantic Web: extension of the World Wide Web through standards introduced by World Wide Web Consortium. Depiction of complex knowledge-relations, that is often expressed by ontologies.

Semantic Web Service: the server end of a client–server system for machine-to-machine interaction via World Wide Web.

Specification: Specification languages do represent various forms of abstraction. This is due to the fact, that specifications often are invented at an early stadium of software development. Unified modelling language (UML), base of numerous studies in this work, is a specification that enables definition on abstract classes. Purpose of specifications is to describe models, tasks and to support interoperability.

Taxonomy: A taxonomy is a collection of controlled vocabulary terms organized into a hierarchical structure. Each term in a taxonomy is in one or more parent-child relationships to other terms in the taxonomy ("The Web Graph Database," 2018).

Visualization: describes the aim of exemplifying comprehension. According to Fill (2009b) it can be described as the "use of graphical representations to amplify human cognition".

3 Business Process Management

Business Process Management (BPM) is a widely accepted approach to manage business processes. Its purpose is to optimize, model and execute processes by the background of aligned strategies and goals. Out of the value perspective, a BPM's purpose is to generate values for both customers and investors. Out of the corporate - organizational perspective, its purpose is to align performance by given economic axioms as 'function of how well independent components are integrated' (Rummler & Brache, 2012).

Thereby, BPM focusses priory at managerial tasks, but has, due to its holistic set up clear impact on executional and operational tasks: According to IT Analyst Gartner "BPM is a discipline that uses various methods to discover, model, analyze, measure, improve, and optimize business processes. A business process coordinates the behavior of people, systems, information, and things to produce business outcomes in support of a business strategy. Processes can be structured and repeatable or unstructured and variable. Though not required, technologies are often used with BPM. BPM is key to align IT/OT investments to business strategy." https://www.gartner.com/it-glossary/business-process-management-bpm visited on 2018/09/29.

Besides management, typically involved persons are process owners, process workers, consultants, process modeler and software developer (Gadatsch, 2003). Viewed by BPM's function, it is the capability to integrate distinct and heterogenous business cases for 'creating innovations and agility' as well as decision support and optimization of business concepts (Wil, Desel, & Oberweis, 2003). Thus, BPM relies on a systematic and planned approach on processes, driven by measurement. It is process oriented and refers to everything that can be processed (resources, contracts, etc.). Further, BPM systems have the capability to bridge 'the gap' between distinct systems and to empower business experts 'to define more efficient business processes and business rules' (Jung, 2009). Consequent to the different capabilities and utilizations, BPM is shaped depending on the purposes as 'method', 'concept' or 'tool'.

The most prominent BPM concept is the 'Life Cycle'. That is the approach to subordinate BPM into phases, tasks and purposes by applying iteration. (Distinct) business models are systematically processed and continuously defined, aligned, executed and optimized, while specifically addressing layers within an organization: Business (value dimension), process (transformation), management (decision taking).

As different phases are aligned and integrated, a 'vast amplitude of adaptability' (Rosemann, 2010) is reached. Remarkable benefit thereby is, to achieve business flexibility and structured, meaningful procedures simultaneously. At literature distinct approaches exist, differing by specific aims and target audience. Weske (2012) aims for evaluation, design & analysis, configuration and enactment. For semantic enrichment purposes Wetzstein et al. (2007) introduce a four-step BPM cycle: modeling, implementation, execution, analysis (table i).

Time, risk and knowledge are meta dimensions in a life cycle. They a) impact corporate action and behavior within a bpm life cycle and b) they have an umbrella function for subsequent executions: planning, decision taking, processing and learning. These dimensions do fund the BPM; and it is clear that they are in tension range amongst each other. E.g. cost reductions are likely to effect quality. Out of an integration perspective, this fact, that is referred to 'devil's quadrangle', is important to consider.

<table>
<tr><th>Life Cycle by Gadatsch</th><th>by Wetzstein</th><th>by Weske</th></tr>
<tr><td rowspan="2">Strategic oriented configuration of processes</td><td>Modeling</td><td>Evaluation</td></tr>
<tr><td>Implementation</td><td>Design</td></tr>
<tr><td>Organizational-technical Transformation</td><td>Execution</td><td>Execution</td></tr>
<tr><td rowspan="2">Execution and monitoring</td><td rowspan="2">Analysis</td><td>Configuration</td></tr>
<tr><td>Enactment</td></tr>
</table>

Table i: Life Cycle Phases (Gadatsch, 2003; Weske, 2012; Wetzstein et al., 2007).

4 Business Process Models

In the following section insight on Business Process Modelling is given. This, due to the fact that the topic of semantic BPM integration relies by broad extent on modeling. Further BPM perspectives, as the execution or optimization of a process, depend on a ‘constitutional’ process (meta-) model: Without having clear, comprehensive abstraction of the funding process, considerations lack of ‘grip’ to shift process’ towards integration and interoperate ability. This fact is even more to emphasize, as BPM is to be ‘enriched’ and integrated by semantics that refer to distinct process models.

First, overview on decent process modeling preconditions and introduction on widespread methods is given. This, due to the aim of motivating the lack between spheres, and due to the fact that modelling methods range from particular purposes – as to onboard business into modeling via graph notations – to focus on specific events.

Then, insight on meta models is provided. Since modeling is a widely ramified field of interest, focus is put on constituting matters.

Preconditioning for process modeling is a set of requirements that is indispensable to achieve integration: Clear modeling aims are crucial since undefined purposes lead to non-fitting unfocused models, lacking efficiency. Modeling cannot be achieved just from scratch (Becker, Probandt, & Vering, 2012). Therefore, documentation of the existing inventory, interfaces and both implicit and explicit semantics is essential. This leads in consequence and broad context, to full understanding of a business idea (input – value generation - output), reflecting restrictions, rules and (strategic) aims.

Further, controlling and steering functions, as integrated benchmarking, are eased by applying business process models. To reach global and specific aims, distinct corporate views, which span from functions and organization to roles and applications, have to be considered. Since models are ‘representations for originals for purposes of a subject’ Becker, Probandt, et al. (2012) proposes principles of ‘good’ modelling that have to be considered.

Accuracy: is given, if preconditioned syntactic and semantic model requirements are correctly given. Syntactical correctness is given, if the application of the model is consistent with its meta-model. Semantic correctness is, due to the given example below (‘department’ may be understood as hierarchical upright or equal), not as straight forward. Relevance can be seen as the requirement to abstract just those items, that are needed, and not just because they occur.

Efficiency: refers to self-explaining requirement, not to spend more effort on a model as subsequently may be gained out of. Soundness is given, if a model is clear, easy readable and understandable, etc. Comparability, shall ensure comparison of ‘as is’ and ‘to be’ comparison. Taxonomy refers to big or accumulated models. If loosely, unaligned modeling from different sides is applied, taxonomy will not be achieved.

For systematic goal drill down of modeling tasks, these principles are meaningful as well. More practically this refers to requirements as of: ‘Each process starts and ends with an event’. ‘Events and functions alternate’. Connectors exist out of ‘AND’, ‘inclusive / exclusive OR’.

4.1 Modeling Methods

Modeling methods are several fold important for integration discussion: They partly consist semantics, e.g. type semantics: But they do not necessarily represent full reality (semantics). Since semantic process modeling is not happening just from scratch, but rather based on existing models, from this perspective, ‘conventional’ modeling languages are the starting point for semantic BPM integration. They may be used as feeders for semantic integration purposes.

Practically informal, semiformal and formal models exist. Informal, textual, describe and clarify. Semiformal graph standards are utilized to visualize, simulate and transition into executable specification. In the following most prominent model languages are briefly introduced. Three types are dominant:

1. Execution standards like the Business Process Execution Language (BPEL)
2. Graphical notations like Business Process Modeling Notation (BPMN)
3. Distributed systems as petri nets

Whereas it is to note, that distinct standards have distinct utilization scopes, ranging from inclusion of business experts via graphical standards, to interface and automation purpose of execution standards: “Graphical standards are currently the highest level of expressing the BP (i.e. most natural to humans) while the lowest (i.e. most technical) level is the execution standards. While graphical standards diagrammatically express contemporary BP, the execution standards aim to automate BP via computers” (Hoang et al., 2014).

Graph notation: BPMN: Business Process Modeling Notation intends to open and attract the modeling sphere to persons, not being IT natives, e.g. business analysts. Therefore, it consists out of an easily understandable, mostly self-explaining, notation. It is based on process graphs that reflect processes, combining modeling elements in distinct classes. In its processing the BPMN shows similarities with EPC, as activities and events are triggered. Vertical integration is possible, since decision points take over functions of connectors (Becker, Probandt, et al., 2012). Well recognized BPM tools and systems are relying on it. E.g. the ADONIS tool supports amongst other methods BPMN 2.0.

Entity relationship model (ERM): It is funded by two constructs that can be extracted right out of its name: Entities that represent excerpts (entities) out of 'reality'. Consistent entities are combined via entity types. Entities may be further specified by characterization via Attributes. Relationships express semantic context. E.g. risk department (entity) asses risk profiles for (relation) retail department. Cardinalities further characterize the relation by stating how often the relation is to be used. Classification ensures the sorting on hierarchical layers: the risk department may be assigned to the risk division, retail to private banking.

Unified modeling language (UML): Similar like ERM, UML objects are referred to classes (UML is labeled as 'class diagram' too). Via these classes objects are associated with each other. E.g. outstanding loans may be referred to a specific risk class. The reference may be applied back-to-front too. UML further enables assignment of attributes.

Event drive process chain (EPC): are vastly applied within BPM systems. Integrated systems do rely on this language. Process models that are established along EPC use 'directed graphs' consisting out of function, event, control flow and connector. Now an EPC based process model describes which events are triggered by which functions (activities), and which events triggers which function. Along its elements a process is to be described via EPC on a fixed abstraction layer, but due to the passive character of events, events do not show decision capability (Becker, Probandt, et al., 2012). By means of fine tuning process elements, (vertical) dissolution is enabled. By means of interfaces, process models can be intertwined horicontally. Since process modeling is described as error prone and costly (Ferilli & Esposito, 2013), it is argued extracting modeling pieces from execution is economically preferable.

Distributed system / Petri Nets: Another widely spread process modelling language is the so-called petri net, also referred as directed graphs. Places (conditions), token, control flow (transition) and edges allow the description of a specific process. Extensions, like time specifications or model hierarchies, have been applied. Thus, petri nets are described by tendency as complex and big, and therefore it described as hard to decode (Becker, Probandt, et al., 2012).

BPMN, UML and EP are sometimes, due to their ability to model control flow of business processes, referred as 'workflow graphs' (Vanhatalo, Völzer, Leymann, & Moser, 2008).

4.2 Meta Model

Are models of models in the sense, that they are a 'model of a modeling language. Thereby, it is to be stressed, that precise contextual distinction is crucial. According to Favre (2005) "A meta model is a model set of models" and funds a 1:n relation. And "a meta model is a model that defines language for expressing a model". The relationship amongst layers is to be visualized by 'metamodeling hierarchy' and the task of "creating a metamodel is the task of creating a language that is capable to describe the relevant aspects of a subject under consideration that are of interest for the future users of the created models" (Höfferer, 2007).

As outlined in the definition section meta modeling between meta models and ontologies is to distinct. Whereas meta models do have their focal point on "syntax of a modeling language which means that all available modeling constructs are defined as well as valid ways to combine them" (Höfferer, 2007). Although semantics are given too (e.g. the term 'entity' comprises semantics), its peculiarity is minor and non-explicated. This lack of explicitness now is to be closed by ontological means. As ontologies are bi-directional utilized for description (Kappel et al., 2006): A) semantics of modeling language constructs, B) semantics of modeling instances.

For the purpose of integrating business processes this twofold characteristic is beneficial, since ontologies are capable to intertwine specific domain semantics with a process model.

Thus, to achieve semantic interoperate ability, the combination of meta models and ontologies, holistically covers this aim.

Via semantic annotation reached standardization of models and model elements may be reached also via 'technical term vocabularies' too. Thus, upside of ontologies is, beside the formal representation of domain knowledge, machine-readability of ontologies. Therewith, even incomplete or fragmentary information may be complemented by automated (machine) deduction. In consequence, semantic interpretation, query and validation are enabled too (Thomas & Fellmann, 2009). Insofar the combination of meta models and ontologies is appropriate, as augmentation of respective blank spaces is reached.

Since the newly modeling of ontologies and meta models are time-intensive, complex tasks, two sophisticated modeling technics, by the background of semantic integration, are introduced: the reuse of process fragments and auto-completion. Reuse of process fragments, tautologically claims 'usability-identification'. If detected e.g. by a business analyst, those fragments, sometimes also described as logs or events, are stored within business process repositories for further use. Auto-completion is now the ability to automatically reuse selected fragments within an uncompleted process model.

5 Semantic Web Technology

In the following an introduction on semantic web is provided. This is due to the fact, that the semantic web technologies, namely ontologies, have a core stake in discussions on semantic BPM integration. Semantic Web is an extension of the web. Purpose is to ease 'meaningful' data transmission and utilization along the web. E.g. a web document shall enclose the meaning of the German term 'bank', that may, taken by itself, stand for a financial institution, a sand bank at a river, or a bench in the park. Since machines do not contextualize such implicit information, the 'real' meaning is explicated by a bundle of technological standards, like 'URI's', RDF's and 'OWL'. How those standards are hierarchically layered in a stack (sometimes referred as 'semantic web cake'), is illustrated in table ii. Thereby each layer utilizes capabilities of subordinated languages. All of the standards aim to support machine-readable and transferable (semantic) data but fulfill distinct tasks thereby. For instance:

RDF Resource description framework describes statements logically, similar to UML (class-diagrams) or the entity relationship model.

URI's (uniform resource identifiers) are to identify entities, that may be both abstract or physical resources. Further URI's enable to link data to 'congeneric' data.

Ontology, that is most prominent in context of semantic BPM integration, is utilized to formally define vocabulary. The so called 'web ontology language' (OWL) bridges (specifies) terms of a specific domain into processable.

Ontology in this context is a ‘knowledge graph that describes concepts and instances in machine-readable form’ (Thomas & Fellmann, 2009) and based on RDF and RDFS most ontologies use the standard OWL (Lautenbacher & Bauer, 2006).

Whereas knowledge is a ‘combination of taxonomies, axioms, relationship and data definitions, restrictions, and rules that apply to so-called individuals/instances and their relationships, that may also be stored in an ontology’. Beside machine-interpretation, human ‘readability’ is given too.

The ontology itself is grouped twofold: a ‘t-box’ organizes taxonomy like semantic definitions, whereas the ‘a-box considers instances ‘that need to be asserted in context of the given definitions and boundary conditions of the t-box’ (Elstermann, 2017).

In context of semantic process modeling, ontologies are claimed as precondition, (Thomas & Fellmann, 2009). For the construction, existing ontologies like the TOVE (Toronto Virtual Enterprise) may be utilized. For specific industry standards translation further ones, like ‘eClassOWL’ were introduced (Hepp et al., 2005). Another approach to generate an ontology, was to take over existing semantic structures (relation models) of an enterprise (Rivera et al., 2008). Thus, if terms of distinct ontologies are applied, the resulting ontology may be further structured by an ‘upper ontology’.

6 Literature Review – Approach Description

In the following section a summary on the semantic business process management literature review is provided. First, search techniques, sources as well as key words and its delimitation are described. Subsequently a brief overview on findings will be given. Lastly segmentation and drill down of the reviewed literature is concluded, that will be base for the following detailed review. Remark: (sub-) categories summed up, do not hit the grand total of 99 studies, refer to the fact of a) heterogenous or b) unassignable content that does not fit specific categories discussed.

Key Word Search & Source. The search for literature was based on the key words "semantic" and "business process management". The keywords were combined with a logical "AND". In order to get a vast overview, the search was done twice, first without using quotation marks, then using them as an operator. Restriction has been applied on the search fields, that were narrowed to title, abstract and key words. The time period was set from 2005 to 2018. LitSonar, Google Scholar and the University of Vienna Library online sourcing platform have been applied as starting point for the research. Subsequently major online databases have been screened: IEEXplore, ACM Digital Library, AIS Electronic Library.

Matching. Roughly 450 articles have been depicted based on the abovementioned search. In order to select only articles, fitting properly to the defined scope, in a first iteration abstracts were screened. Mostly articles that were referring only in a commonly way to "Business Process Management", tagged for instance by the publishing house as diffused term, have been deleted. Solely literatures referring to Business Process Management as a concept, tool or method, trying to extend that concept by semantic means, have been considered. Further concrete subcategories of semantic BPM have been kept. E.g. if a scholar circles semantic BPM Modeling and is explicitly referring on BPM, respective study is considered. That screening diminished the corpus to 125 studies, that have been further examined.

Now, the corpus has been examined in all its details. Sorting on logical context and segmentation on semantic layers has been applied, whereas findings and details will be subsequently presented. In order to ensure rigor, a back and forward search has been applied too. Research papers, that match the defined scope were checked on presented references. Meaning, ex-ante literature referring and fitting to the scope, is coped too. Analogue, ex-post check on papers, that have been cited, was applied too. The final corpus, scoping semantic Business Process Management, amounts 94 papers.

Sorting. Literature sorting was applied threefold, vertically, horizontally and amongst horizontally driven focal points layered at index III and IV:

A) Based on technological hierarchy, as shown in table ii, studies have been firstly tagged by index layers. If assignment was blurred semantically, it was quantitively measured by simply extracting and counting terms based on the three stacks shown in figure a.

B) Since studies do show an overlapping scope and therefore were multiple tagged - dominant index characteristics were tagged in a second iteration.

C) Examination based on technological, hierarchical and numerical occurrence justification, does provide only partly insight on scholars' intents on a cross-sectional subject field. Therefore, seven types of purpose have been assigned to meet means to its full extend. By progressing the work, subject fields have been synchronized to a final set of 4 study types. Whereas integration is parenthesizing matter for the whole literature corpus.

Distinction on subordinated granularity is applied the following:

- Type 1 Integration by applying

  A) Meta Models

  B) Ontologies.

  Alignment technics, design patterns and frameworks, architecture and fundamental approaches are herewith discussed.

- Type 2 – 4 consists out of

  A) Integration by means of (domain) extensions

  B) focal interest of integration like quality assurance

In the following, findings and measures are summarized at glance. Subsequently detailed insight on findings of the six established focal points is provided.

6.1 Findings at glance

Semantic Business Process Management as whole, self-contained system, is discussed by 27 studies. Meaning, that respective scholars do provide input on parameter that refer to the complete BPM concept, that discusses

a) the life cycle concept as core entity
b) a self-contained, semantic business process management system is proposed
c) a semantic BPM engine or tool is proposed.

67 papers discuss specific fields of semantic integration and subordinated domains of integration as how to ensure modeling quality by semantic BPM integration. Most prominent in that residual stack are papers referring to specific aspects of process modeling, like semantic integration, or modeling aspects of various IT and Business layers. Thus, it is to state, that the whole examined scientific corpus treats semantic business management as a modeling matter. Studies dealing with specific semantic domains, e.g. ontologies, its capabilities and utilization, do implicitly refer to the modeling hierarchy as seen in table ii.

Thus 86 studies do discuss semantic integration by referring to a modeling perspective, whereas remaining 8 studies refer on examining tools for semantic integration or providing paradigmatic overview.

Semantic Technology. Looking at the purpose for applying semantic technologies, it is ‘processing’ that is the dominating driver to achieve semantic BPM, 79 studies refer to it. Processing thereby refers to establishing ‘automation’ within the Business / IT bottleneck, as well as to semantically supported modeling. Whereas it is to denote, that out of 79 studies assigned to ‘processing’ 57 studies are cover besides the general purpose ‘processing’ further purposes that are ‘query’, ‘visualization’ and ‘monitoring’.

Not surprisingly ontologies are the semantic technology, that is absolutely dominant. 55 studies discuss the design, (specific) capabilities and domains. The remaining have either overview / paradigm characteristic or put the focal point on modeling aspects by the background of ontology use. Based on the ‘bipolar’ (Business and IT) characteristic on the ontologies subject, it is distinct that majority of 41 studies discusses either organizational or business specific domains. 12 studies do noticeably refer to process domain. Other standard technologies, as the resource description framework (RDF), do show impact, but are just randomly discussed and considered.

Modeling Languages. Modeling Languages are mostly discussed by the semantic perspective. More precisely, 64 studies are discussing semantics, thereof 17 are referred to 'inherent' semantics, 24 to 'behavioral' and 'inherent'. Type related semantics are considered 10 times.

Business Process Modeling Notation (BPMN) related discussions, as semantic extensions, is topic for 9 scholars. The business process execution language (BPEL) and its semantic usability is discussed 5 times.

Similar to the OWL ontology, BPMN and BPEL have in preconditional and implicit context a vast impact and are therefore mentioned in roughly two thirds of the works. E.g. when utilization of business artefacts or execution logs is discussed.

6.2 Integration – Types

Type 1: This type scopes studies that discuss integration of semantic technologies into business process management. Integration therewith is defined based on the definition section. Integration covers this work as funding layer.

Thus, analogue to parenthesizing modeling subject, semantic integration is to depict as meta-topic concerning almost the whole literature corpus. Therefore, findings reflected in this section, concern integration in front of two dimensions: a) meta-models and b) semantic technologies. 30 Studies are referred to this type.

Furthermore, specific considerations, like semantic extensions of BPM languages, or quality assurance, are brought up within type 2 to 4. The focus on residing 40 studies is put on subsequent enlightened subcategories like semantic extensions of bpm notations or ensuring quality by (semantic) validation.

64 studies discuss the subject of semantic integration too, thus out of specific focal points introduced below.

Type 2: Semantic extension of process description languages (specifications). Aim of respective studies is to enrich exiting, widely acknowledged specifications with semantics. Most prominent are extension via Petri Nets, EPC (even driven process chain), BPMN. 10 Studies.

Type 3: Automatic synthesis and automated planning of process models. Due to the fact of ongoing change within (business) environments, it is proposed to catch dynamic conditions by agile and automated modeling. 4 studies.

Type 4: Refer to Quality Assuring studies. Quality assurance thereby comprises fields of verification, validation reasoning and constraint handling. Scholars aim for quality assurance, by applying verification or validation. 28 studies.

Note: if (sub) groups do not sum up to the overall corpus of 99 studies, studies cannot be assigned to a specific type. This is the case with e.g. review studies. Reverse, studies are partly mentioned twice, e.g. in case they consist out of general deliberation, as well as specified ones.

7 Integration – Bringing Semantic Technologies and BPM together

In the following section an overview on findings on examined literature is provided. The funding and cramping parameters are meta models, ontologies and connection manners (semantic lifting). Findings on set up, purposes and domains are given.

As indicated scoped are mostly organizational domains (business processes) in integrated modeling context. Scholars approach these fields mostly out of a design and integration view. IT specific and domain specific, like IT processes or branch domain ontologies, considerations have secondarily impact.

First insight on general purposes is given, bottom-up specifics to sub-ordinated considerations accompanying semantic BPM integration.

Practically, semantic integration requires modeling hitherto semantically plain, but existing technological BPM approaches by help of meta models and semantic technologies (ontologies). The widespread integration approach is, that domain knowledge is visualized and modeled by means of models, corresponding meta models and (business) imperatives in the form of data and artefacts.

Technological driver is, that modeling languages like the Unified Modeling Language (UML), are widespread and used in context of process modeling (van der Aalst, Desel, & Oberweis, 2000), but do support only type semantics consisting out of syntactical and structural information (Karagiannis, 2007). To make inherent semantics explicit, a procedure is applied called “lifting” (Kappel et al., 2006), or “ontology anchoring” (och Dag, Gervasi, & Brinkkemper, 2005). As enabler of this procedure semantic elements and denotations, in the form of ontologies, are created. Partially existing ontologies are just extended by semantic means.

Drivers on describing semantics properly are sorting and grouping, dependencies, expressing and other design paradigms that are exemplified by e.g. frameworks and patterns. Out of BPM life cycle perspective, integration is attributable with the design and moreover modeling phase, since models are aligned and integrated. Out of a negative limitation perspective, studies continuously point out, that non-integrated spheres mandatorily require ongoing, gratuitous human intervention and effort at the Business - IT interface (Hepp et al., 2005).

Sources that are used to close the gap are two dimensional in various manifestation:

A) Frameworks of libraries, reference stacks, artefacts and ontologies

B) Existing process models that either are newly set up or reengineered by semantic means. Referring to an ‘as-is’ or a ‘to-be’ status. Utilizing data mining or reconstruction and reverse engineering; based on e.g. ERP data; is described as third e.g. here: Hepp (Hepp & Roman, 2007). Thus, amongst the examined literature within and due to the defined scope this dimension has no impact.

Argumentation on closing the divide are to be characterized twofold as well:

A) Organizations do have demand for unified view (representations), in a machine-readable form, on business processes: Common machine-readability enables querying process’ both semantically and holistically. Therefore, all reviewed authors claim – at least implicitly - machine-readable, bi-directional usable knowledge representation as precondition for semantic integration. E.g. (Hepp et al., 2005).

B) Emphasizes on dynamic environments accompanied by ongoing process up dates, that business organizations are operating in. It is stated, e.g. (Hinkelmann et al., 2016), that one-time modeling an intertwined, semantic process space does not satisfy business-reality due to continuous process changes. Therefore, demand for agility and ongoing respond and model adjustment to changes is postulated. Subordinated aims, that are extracted, will be separately discussed below. The “gap” or “IT-Business divide” itself, that is to overcome by integration, is constituted by multiplicity of IT systems and lack of resources that enable bridging (Hepp & Roman, 2007).

For this work, as stated in the definition section, integration is determined as intertwining existing, heterogenous process models, against the background of linking corresponding meta models and its elements, to gain transcend business process semantics. Bottom-up to vast consensus on problem 'diagnosis', proposals on problem solving do vary. Still, studies can be aggregated into two main approach characteristics:

A) Integration by meta modeling. Also described as "linguistic metamodeling" comprising syntax, structure and type semantics (Höfferer, 2007).

B) Integration by use of semantic web technologies, discussed as 'ontological metamodeling' or 'lifting'.

Both approaches are funded by the fact, that direct, meaningful mapping between models is hardly established. Nevertheless, the distinction is to see theoretically, in order to abstract and emphasize on a specific approach. Practically, scholars apply proposals that ultimately do show a combination of both (Kappel et al., 2006), as ontologies do require some kind of a meta model consideration. Recurrent theme of semantic integration, is the question on how to align heterogenous process models, technologies and claims, as schemed in figure a, under the side conditions of maximal automation and semantic completeness.

- 10 out of 37 studies approaching integration via discussing meta modeling topics.
- Absolutely dominant meta modeling aspect is design, in few cases implementation or use aspects are enlightened, and if so, subordinated.
- Sorting meta model – ontology linkage by manual, adaptive, or computational approaches, adaptive approaches dominate significantly.
- 27 are discussing semantic integration by focusing on the semantic web technology perspective, namely ontologies and its functionalities, business domains, etc. Sorted by purpose, 20 scholars deal with domain related questions, 11 refer to process (e.g. via artefacts that are involved for process realization), 3 point out an organizational focus (e.g. structure of a process).
- Analogue to the parenthesizing modeling subject, semantic integration is to depict as meta-topic concerning the whole literature corpus. Whereas the focus on residing 40

studies is put on subsequent enlightened subcategories like semantic extensions of bpm notations or ensuring quality by (semantic) validation.

- 12 integration related studies discuss semantic business process management as whole (BPM in narrow sense) and provide holistic solutions. 10 refer to the inherent BPM concept ‘life cycle’. 10 suggest a semantic BPM engine.
- Authors tend to emphasize at the beginning of the examined time span (2005 – 2018) on exigency of meta-modeling and intertwining domain spaces via ontologies. Either semantic BPM integration is discussed out of a holistic view, considering BPM as a whole concept (e.g. by referring to the entire life-cycle), or discussing specific parts (e.g. specific domain ontology utilized for integration).
- Whereas recent works tend to put focal point on claiming to consider continuous alignment and integration works.
- Looking at origins of process models it is found: ‘older’ studies tend to deal with Modelling EPC and Petri Nets. ‘Younger’ studies tend to deal with BPMN

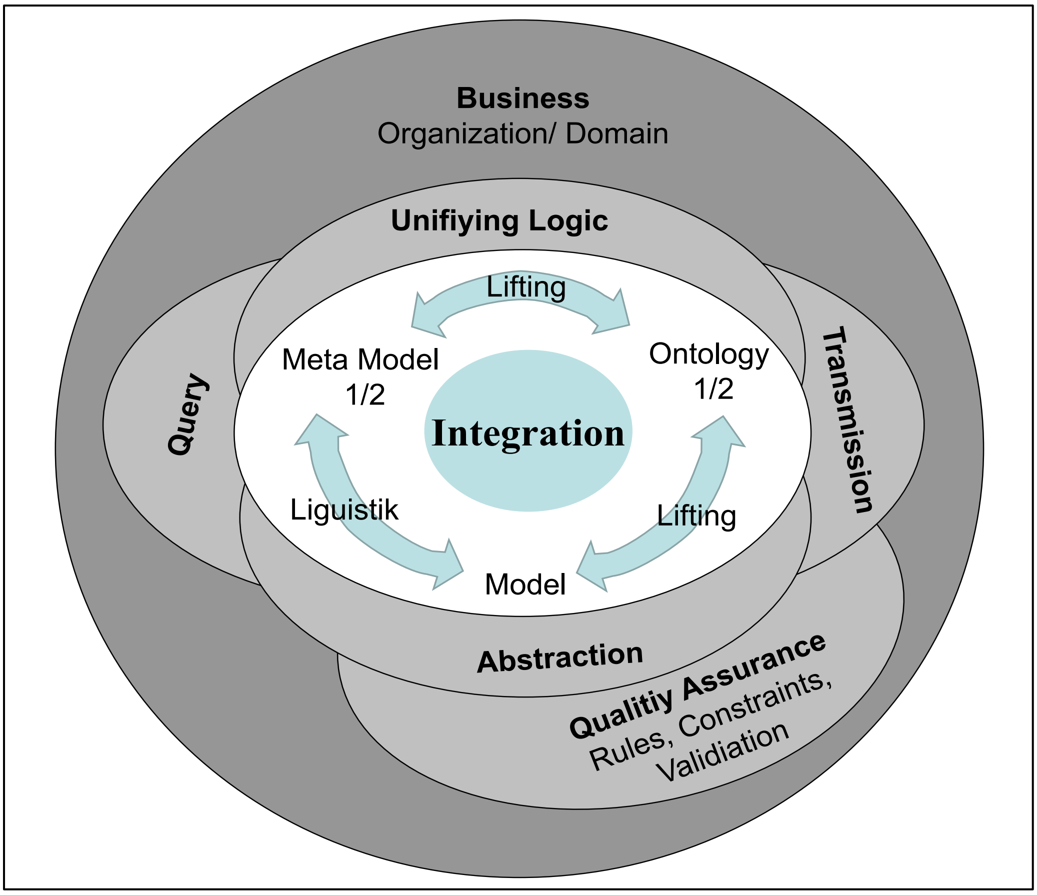

Figure a: Semantic Business Process Management. Funding Layers

	Semantic Business Process Management **Virtualize** **Query** **Monitoring** **Processing**									
Index I	**Semantic Web Technology**		**BPM**		**Process Modeling Method**					
Index II	Standards		General Concept Life Cycle	Proces Model	Modeling Language				Modeling Technique	
Index III	Trust Logic & Proof Ontologies RDF Schema Resource Description Framework XML Unicode & URIs	Ontology Purpose Organisational Process Domain	Modeling Analysis Execution & Workflow Monitoring		notation static / dynamic	syntax	semantics Structural inherent / type	behavioral Semantics	modeling procedure	mechanism & algorithm generic algorithm specific algorithm hybrid algorithm
Index IV	Ontology Types Domain web processing organizational fuzzy Ontology	OWL FA WSMO GPO sBPMN sEPC sBPEL BPMO BPEL4SWS ...	BPM Modeling Tools ADONIS ARIS SBPM	BPM Engines Projects & Case Studys SUPER Telefonica health-care system		execution standards BPEL BPML WSFL EPC interchange standards XPDL BPDM	graph notation BPMN UML	distributed systems Petri Nets		Optimization linear convex
	< 4 Intersection Types & n Subtypes >									

Table ii: Semantic Business Process Management. Conceptual Stack: Semantic Web, BPM, Process Moedling

7.1 Semantic BPM Integration – Type 1

Ontologies**.** Utilizing ontologies for integration is founded amongst literature due to A) practical, user-friendly oriented reasons, like the eased and 'low-threshold' connection to specific domains and B) in order to cover full semantics. Especially those 'inherent' semantics, that are not covered by other means. Thus, since no technological, axiomatic precondition exists to apply ontologies in BPM, authors stress qualitative, conclusive arguments, why ontology use is beneficial compared to plain meta modeling.

Karagiannis and Höfferer (2006) emphasize the share of conceptualization and the 'excellent means to solve integration' by the background of syntactical, structural and semantic heterogeneity. Compared, meta models often are just valid for specific tools or organizations (Karagiannis & Höfferer, 2006) and 'inherent' semantics are not captured via meta models. Shen et al. (2007) emphasize that interaction, especially in respect of "complex relationships" such as specified (business) domains, ontology use, eases automatically discover, invocation and composition.

The descriptions of ontology integration is funded by three domain perspectives (Pedrinaci, Domingue, et al., 2008) that distinct participating spheres as shown in figure b, and that implicitly covers the general IT / Business divide:

- Domain Ontology that captures information of a specific entity (e.g. finance enterprise).
- Organizational Ontologies are to capture information out of the process of the business sphere.
- Process Ontologies capture the procedure of a process.

Organizational and domain ontologies are seen as part of the business side, and are therefore of special interest for a semantically integrated BPM: "Process related information (e.g. ontologies) describes the structure of a process (i.e. tasks, control structures, links etc.), whereas organisation related ontologies provide a description of enterprise artefacts (i.e. actors, functions etc.) that are utilised or involved in the process realization. The domain ontologies provide information specific to an organization from a given domain" (Filipowska, Hepp, et al., 2009).

Along the examined literature, organizational related studies are absolutely dominant. Whereas domain ontology related studies refer to specific branches or entities and are most often accompanied by case studies. Requirements of specific branches; e.g. Hua, Zhao, and Storey (2010) describe what it requires to set up a domain ontology. Similar to 'domain ontologies', 'process' oriented ontology studies are discussed secondarily, as they are not seen as primary impact variable of the Business / IT divide. An example on required modeling steps of an semantically funded BPM process is given by Fan, Hua, Storey, and Zhao (2016).

In regards of organizational ontologies, various scholars provide insight on modeling-guidance, required modeling steps and sequences. Issues of resources and goals are focal point on studies referring to organizational ontologies too. Thereby, two persisting requirements, are stated on organizational ontologies: a common vocabulary and a content vocabulary. The first refers to a set of integrated, a common set of transferable terms and notations as on meta-model layer level, a set of specifications has to be founded, that is "understood" by its technological counterparts within the same (meta) layer (Kappel et al., 2006).

The second refers to the requirement to fully scope business processes. Analogue to expressive process-performance measuring, comprehensive and extensive coverage has to ensured, in to apply 'meaningful' semantics.

Distinction and directive on what organizational ontologies consist is provided by Filipowska, Kaczmarek, Kowalkiewicz, Markovic, and Zhou (2009). A paradigmatic set of six ontologies, describing aspects of an organization, comprising entity's hierarchy, functions, goals and restrictions:

- 'Organizational Structure Ontology: covers organizational hierarchy, shows how elements of organization's structure work together in order to achieve organization's goals.
- Organizational Units Ontology. This ontology provides specification of typical units that may be found in a company.
- Business Roles Ontology. This ontology provides a common meaning of concepts related to roles featured by organizational members (i.e. actors).
- Business Functions Ontology. This ontology provides a hierarchy of different functions that may be carried out within the company.

- Business Resources Ontology. This ontology describes applications and resources that should be involved when carrying out certain processes or that may be results of certain task within a process.’

Business Goals Ontology (BGO). Goals may explain why the processes exist in the organization; examples include customer satisfaction, growth, etc. BGO models a hierarchy of business goals and provides a set of relations between them to enable goal-based reasoning.

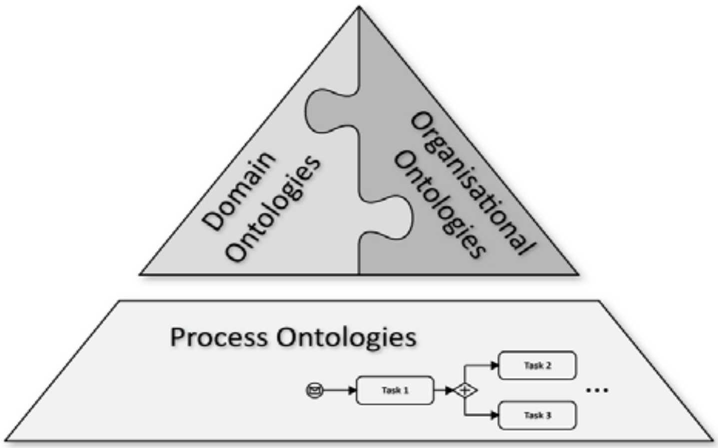

Figure b: Ontologies by Spheres and Purpose (Filipowska, Kaczmarek, et al., 2009).

Similar distinction and guidance is shown here: Hepp and Roman (2007). Based on bundled, depicted modeling domains, covering core process, organization and resources, functions, data, provisioning, rules and constraints, strategy and business logics, a set of competency questions and instructions is presented. The distinction thereby is a ‘blueprint’ for (upper) ontology coverage and representation.

7.2 Artefacts and Ontologies

To reach correspondence between ontologies and business intentions, “reality” fragments in the form of artefacts are assigned. Thus, artefacts are, as described within definition section, fundamental for ontologies. Most often they are denoted in context to specific (meta) models and ontologies. Meta models to the task reflecting abstraction granularity (layer). As the integrational task is to establish “translation layer that allow the mapping of language elements and model elements” (Karagiannis, 2007) artefacts are to be described as preconditioning elements. Analogue to scoping ontologies, it is to extract or derive elements that do fully represent a business process, considering accompanying organizational purposes.

Consideration on further coupling to corresponding domains is the second dimension therewith.

Therefore, literature relating to artefacts, circle two sides of a medal:

1. Describing properly artefacts and ontologies in order to mirror reality to its full extent. Works are driven by design and integration proposals are based on paradigmatic view.
2. Modeling driven considerations (integration with semantic technologies and (meta) models).

Gaining of artefacts is described twofold: Extracting fragments, e.g. out of ongoing process executions via "event logs", which are used as feeders of semantic repositories. Secondly, newly designed frameworks that cope (business) reality. Whereas the design of repositories (database schemes), taxonomies, set-up of dictionaries (repositories) and assignment of meta layers are discussed too. Further, the development of new notations, or extending existing ones are subjects, are discussed in close context. Creation of artefacts itself 'most often corresponds to different modeling languages and, therefore, metamodels' (Karagiannis, 2007).

Pedrinaci provides proposals for artefact selection in regards of specific organizational domains to ensure consistency (Pedrinaci, Domingue, et al., 2008). Artefacts as ontology "feeders" out of business context, are discussed in terms of axiomatic principles and by "querying the process space" here: (Filipowska, Hepp, et al., 2009) Artefacts that shall be (re)-usable along different phases of BPM here: (Hepp & Roman, 2007)

Markovic and Kowalkiewicz (2008) give insight on how to select and link business goals (artefacts), to ontologies. He examines how the linkage of artefacts to ontologies is established via meta layer. Further, insight is given, on how to extract artefacts in case of contradicting business goals. Artefacts in regard of the BPM life cycle and business goals are discussed here: (Wetzstein et al., 2007). Artefacts to semantically establish specific BPM rules and integration of artifacts to establish business rules is discussed here: (Wetzstein et al., 2007) (Hull et al., 2011)

A further field of interest concerning artefacts, refers to the question how and which artefacts to capture out of an ongoing process: Betzing (2017) presents the design for automated capturing process events and shows how to transform them into reusable artefacts. Extracting artefacts, that already considers subsequent alignment with (heterogenous) models is methodological introduced by Fengel (2014).

7.3 Ontology Alignment

Determining correspondence between process space representing artefacts, needs to be accompanied by ensuring correspondence in between ontologies and the models they are referred to. This purpose is labeled as “ontology alignment” (Jung, 2009), or “ontology matching” (Kim & Suhh, 2010). Two approaches are detected:

1. Manual alignment for building a whole business process ontology in a BPM system. That approach is discussed for instance by Cabral, Norton, and Domingue (2009).
2. Automated alignment between business processes of distinct BPM systems. Amongst other, Barnickel, Böttcher, and Paschke (2010) introduce this approach by implementing a “mediation editor”.

Whereas fundamental scholar literature (van der Aalst et al., 2000), distinguishes between four dimensions of formal alignment:

- Similarity vs logic
- Atomic vs complex
- Homogenous vs heterogenous
- Type of alignment

These dimensions are discussed are qualitatively amongst studies. Semantic BPM literature thereby guides through sorting steps and assignment in front of these dimensions: Filipowska, Hepp, et al. (2009) support a network of logic and consistent ontologies. Whereas ‘consistent’ requires that “ontologies are based on compatible paradigms, have a compatible degree of detail, and include at least partial sets of alignment relations, which allow data interoperability”. Others solve the alignment task by inventing a bridge ontology that is based on “reusing existing conceptual models and relating the business knowledge” (Fengel & Rebstock, 2010). Thereinafter, Fengel (2014) proposes a method that allows reuse of legacy models and automatedly determining of semantic similarity. Formal driven approaches on the other hand circle around questions, that span between

- Points of data manipulation
- Transition and Notation

- Abstracted views (meta layers).

Amongst examined literature, formal integration approaches tend to extract required information (artefacts) out of execution standards like the BPEL (business process execution language) respectively advent versions like BPEL4WS. These approaches are routed by performing a transformation from the execution standard to a semantic (web) ontology like OWL. A comprehensive overview on ontology alignment is provided here: (Jung, 2009)

An introduction on which ontologies are applicable for semantic BPM engineering is given here: (Kerrigan, Norton, Simperl, & Fensel, 2009)

7.4 Meta Models.

Meta models, the "vehicle for conceptual modeling" are discussed in a) respect of their relation towards ontologies, or b) their linguistic coherence and integration in subordinated models, or superior meta-models (Woitsch, Karagiannis, Plexousakis, & Hinkelmann, 2009). Thus, closely related are considerations on 'semantic lifting'.

Meta models are characterized by two main perspectives: as a concept or as technical approach (Fill, 2009a). Analogue to ontologies, among examined literature, conceptual driven commentary on graphic meta models are dominant.

Distinguishing studies by three meta modeling aspects: 'design', 'use' or 'implementation'; design in conceptual context, is dominant. Implementation and domain aspects are sub-ordinated discussed.

A similar picture is given, by differing meta model references by taxonomies:

- Macro or micro design
- Integration
- Domain

The first group, macro design, is dominant. Thereby, macro modeling means the design of 'meta models that can act as templates' and micro modeling refers to descriptions of 'inheritance mechanism'. Design in this context is understood by the root of the term, that refers to paradigm.

7.5 Vocabularies, Patterns & Frameworks

As outlined, a core challenge on integrating business process models, is to identify semantics (model elements), that represent the same meaning and (process) purpose. Therefore, clustering and (pre-) segmentation by means of hierarchical-semantical abstraction and horizontal purpose, are schemed and are discussed and sometimes also labeled as 'frameworks'.

Practically this can be achieved by extracting semantic components from semantic annotations of business processes (Jung, 2009). In consequence, this refers already to integration means, as elements are clustered and abstracted into patterns enclosing the same semantical meaning or purpose: Differentiation at the conceptual approach is most often shown twofold:

a) based on the specific domain (events, time, etc.)
b) their hierarchical orientation.

Meaning that information like logs can be collected on lower levels and abstracted and transferred to higher levels of abstraction and subsequent combination. E.g. shown by Pedrinaci, Domingue, et al. (2008). Generally, between two paradigms is thereby distinct: 'Meta-Object-Facility' (MOF) supports any kind of meta data and 'Ontology Design Patterns' that support sources and target models.

An ontology design patterns is introduced by Damjanovic (2009). Focus is put on the support of transforming knowledge between source and target model. How to 'capture rich semantics' is described here: (Hua et al., 2010). What the design of an ontology pattern requires in a preconditional and set up context, is outlined here: (Filipowska, Hepp, et al., 2009). Frameworks to (pre) segment ontologies is subjected for instance here (Hepp & Roman, 2007). How a framework is modeled for a specific business domain is shown by Markovic, Pereira, and Stojanovic (2008) as well as here: (Assy, Yongsiriwit, Gaaloul, & Yahia, 2014).

A proposal on general process and domain ontologies, that are (pre-) referenced to semantic annotation and support both syntax and semantics is provided here: (Lin & Strasunskas, 2005). Templates distinct among 'model profile', 'model content' and 'model annotation'. Aim at this proposal is to ease structured integration by the help of blueprints, process templates and referring proposition on semantic annotation.

A specific purpose (ambiguity handling) framework is described here: (Fan et al., 2016). Assy et al. (2014) introduce a sophisticated set of ontologies that is located in the telecommunication branch. BPM life cycle phases are covered; focus is placed on automated execution and the reuse of therewith accrued information (process logs) applied. The proof of functionality is verified by a case study.

Also funded by events is the proposal of Bögl, Schrefl, Pomberger, and Weber (2008): Semantic 'patterns' that are based on EPC events (or functions) are utilized to close the gap between semi-formal process representations and formal reference ontologies. Semantic 'templates' are described to bridge between informal and formal, representation. Formal representation thereby refers on concepts, specified by a 'reference ontology'.

Thus, semantic pattern descriptions allow specification of semantic templates (naming conventions for EPC functions/events), lexical structures (grammar of natural language expressions) and analysis rules (instantiation of semantic pattern templates) (Bögl et al., 2008).

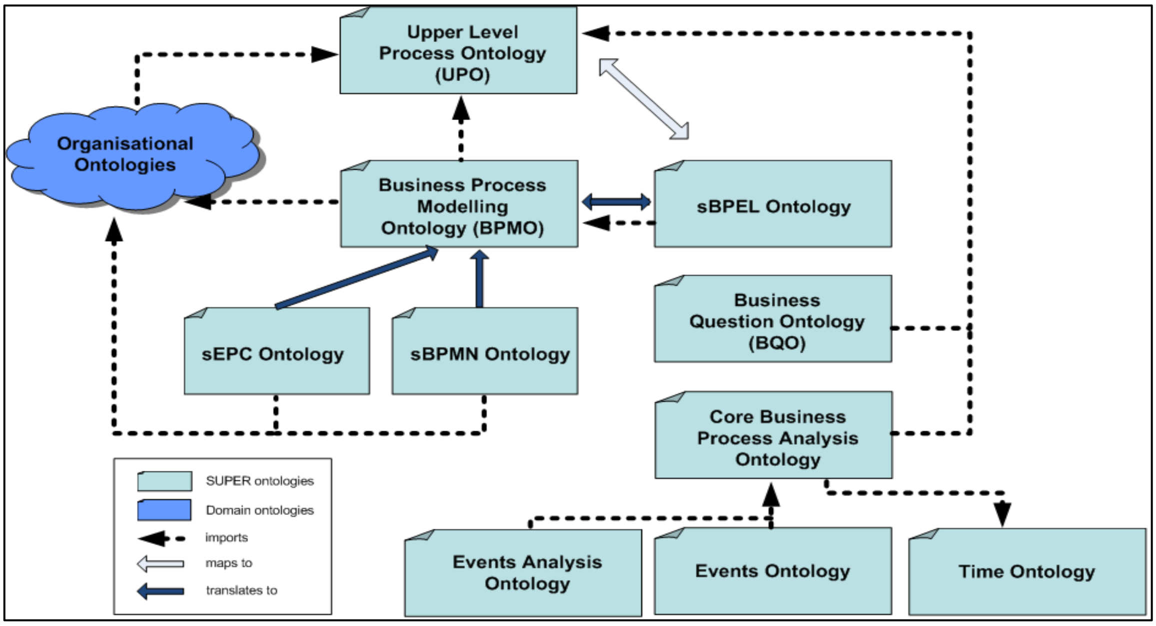

Figure c: Ontology Framework including Organizational Ontologies (Pedrinaci, Domingue, et al., 2008).

As alignment repository between domains and meta layers, scholars propose beside frameworks, 'libraries'. Vocabularies are set up for specific domains, since domain ontologies are likely to be set up in different, heterogenous domains that requires translation support.

The background of disposing a set of exhaustive vocabularies - ideally updated and extended after each process iteration - refers to the demand, having an 'encyclopedia' that semantic

BPM systems revert to. Aim herewith is to ensure “consistent means, that ontologies are based on compatible paradigms, have compatible degree of detail, and include at least partial sets of alignment relations which allow data interpretability” (Filipowska, Hepp, et al., 2009).

Therefore vocabularies purpose refers on supporting knowledge transformation between source and target models and “large bodies of process specifications that can be regarded as libraries of best practice; they are an important source of process models for enterprises” (Damjanovic, 2009). The setup for ‘content vocabulary’ is described here: (Shen et al., 2007). Thereby, the need to include classes, sub-classes, cardinality restrictions and hierarchical inheritance is emphasized. By means of this approach, a set of shared terms, including common understanding of knowledge and information describing, an application domain is provided. Shen and Grossmann discuss such integration based on OWL-S (that is a web service specification) and BPEL.

7.6 Semantic Matching

Semantic ‘matching’ is another integration field on semantic BPM, closely related discussed to frameworks and patterns. Scholars pursue to the question, how to intertwine (‘match’) distinct models and its semantics, that are most often (pre) sorted via patterns or frameworks. Thus, it may be distinct between matching ontologies and linking meta models and ontologies. The letter, linking ontology meta models with linguistic (meta) models is referred to the ‘lifting’ of inherent semantics and will be discussed within the subsequent section.

A matching approach, based on process model similarity identification that supports process model refactoring is introduced by Makni, Haddar, and Ben-Abdallah (2015). This is achieved by employing a comparison matrix, containing all semantic relationships of compared process models.

A functional extension by ontology based semantic matching is introduced by Kim and Suhh (2010). Besides functional properties, this method allows matching of non-functional properties too. A logical driven approach is introduced by Wang et al. (2011) by setting up temporal and logical relations between tasks, to ensure fit amongst heterogenic domains. The intensity of coupling, respectively the degree of coupling ontologies is a challenging task, since both semantic fit and flexibility are aimed. Therefore, a certain degree of accuracy is required amongst literature. Domains and model layers with corresponding ontologies are clustered therefore along frameworks.

Thus, a certain degree of freedom is eligible too, since smooth practice shall not require adjustment after every process iteration. An approach, that shows how to establish and retain a certain degree of flexibility is shown by Decreus and Poels (2008).

A modeling driven matching approach, funded by guidance on ontology-based modeling, is provided by Hua et al. (2010). Beginning by building a domain ontology of the targeted business field and followed by identifying and constructing major activities for key roles. Followed by generating sequence and placing and refining information and deliverables, a generic ontology modeling approach is proposed.

A slight different approach on model matching that is based on a language driven similarity function is presented by Sonntag, Hake, Fettke, and Loos (2016). Using supervised machine learning and a NLP (natural language processing) method, model matching is achieved.

Out of modeling context, linkage of ontologies and meta models is discussed via three approaches: 1. Manual, 2. Adaptive, 3. Computational linkage. The second, adaptive approaches, is mostly based on logical-driven approaches. Pure computational approaches are rather described in workflow related works, that are not in this works scope. Manual linkage has impact in the course of modeling, but studies consistently aim for 'automation'.

7.7 Linking Meta Models and Ontologies. Semantic Lifting.

Now, as meta models and ontologies are described as technologies that enable transmission of semantics, but taken by itself, both are just concepts of abstracting pieces of reality. Description on their capabilities, roles and setup-up does not (explicitly) state, how it is meant to intertwine them. Thus, the crucial question is, based on which mechanism it is proposed to integrate different BPM meta models and ontologies.

Numerous work does not give a statement on this question explicitly. As described, modeling dimensions, frameworks and other characteristics are pointed out. Thus, amongst those referring to such a mechanism, semantic lifting is the mechanism scholars refer to most often. Thereby semantic lifting is the is the "process of semantic enrichment of an applied or to be applied meta models in a specific scenario setting" and therefor acts as a "bridge between many meta models orchestrated to conceptually design organizational aspects” (Woitsch, Karagiannis, et al., 2009). In sequence, semantics are explicit (Kappel et al., 2006).

Explicitly discussed, respectively required is semantic lifting here: (Hepp & Roman, 2007; Hinkelmann et al., 2016; Norton, Cabral, & Nitzsche, 2009; Woitsch, Utz, & Hrgovcic, 2009). Here semantic lifting is described within a semantic BPM system by discussing embedded architecture too (Rivera et al., 2008). Proposed approach is the enrichment and extracting via fragments (artefacts) out of admitted languages as BPEL.

Alternative approaches are advocated e.g. by mathematical, modeling languages as starting points. By means of Petri Nets, that are semantically “augmented”, ontologies are transferred (Poernomo, Umarov, & Hajiyev, 2011). Guidance on how lifting in context with annotation requirements is achieved is described here: (Gao & Bhiri, 2014). According to Hepp and Roman (2007) ontological lifting requires almost always human intervention, since the formal semantics of input data must be augmented by annotations or expressed using richer constructs, provided by the target ontologies. A typical example is that the name of the resource is to be replaced by the unique identifier of this resource in the domain ontology. Thus, this statement may be described as outdated, since especially more recent studies aim for adaptivity and automation in its regard as seen in the next section.

7.8 Recent Claims in Semantic BPM Integration

As stated, studies at the beginning of the examined time span (2005 – 2018) focus on modeling, integrational and conceptual aspects. Whereas studies referring to the second half of the period require increased focus on dynamic environments and therefore claim a paradigm shift.

Semantically annotated business processes can be dynamically composed based on the available components (web services). ‘However, even semantically annotated business processes definitions are static from the point of view of adjusting their instances based on the changed external economic factors’ (Szymanski & Abramowicz, 2011). This circumstance lead to a requirement for more flexibility and even more important, to a new paradigm in modeling. By then the set up and modeling of semantic BPM was rather described as a one-time achievement. Now, a new paradigm was brought up, requiring ongoing adjustments and continuous adaptions:

Hinkelmann (Hinkelmann et al., 2016) requires continuously adapting systems. Instead of model driven approach, a paradigm shift towards “next generation” enterprise information is proposed. Thus, a continuous IT – Business alignment is required. The proposed approach consists on a variant of a ‘Plan- Do-Check-Act cycle’:

1. Establish/adjust goals: strategic and operative goals both for business and IT and their relations.
2. (Re-)Engineer the enterprise: modelling resp. adapting the business, application and technology architectures as well as their relationships.
3. Implement the enterprise architecture and run the enterprise.
4. Monitor the running of the enterprise and recognize adaptation. The work is clustered by business aspects as ‘quality assurance’ (Hinkelmann et al., 2016)

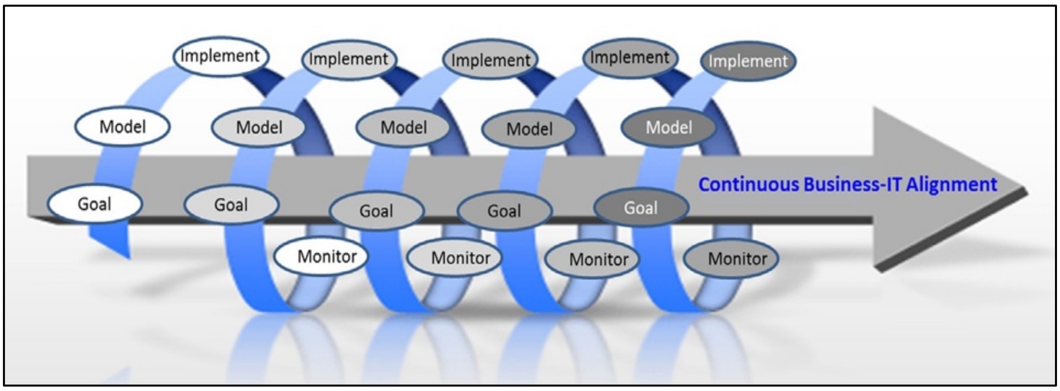

Figure d: Continous Alignment of Business & IT (Hinkelmann et al., 2016).

The Integration approach proposed is still funded by the discussed technics (meta modeling, semantic lifting), circle steadily around a semiotic triangle. Constitutes by semantically extended business process modeling standards, meta modeling and ontologies. The beneficial consequence is, to properly capture dynamic environment and agile processes, as (continuous) meta modeling approaches support both, human-interpretable graphical enterprise architectures and machine-interpretable enterprise ontologies. An approach on ontologies: why process models should directly be described in the web-ontology language, instead of only using it as secondary meta concept is described by Elstermann (2017).

7.9 Semantic extension of existing Business Process Modeling Languages (Type 2)

Another research field of integrating BPM and semantics discusses the semantic extension of existing business process languages. Background is that vastly applied graphical notations do not provide inference reasoning over business processes (Barnickel et al., 2010).

The approach thereby is, to assign concepts, that are formalized via ontologies. In consequence, semantics that originally have been formalized just in natural language, are by then transferred into a machine readable and processable format. Since semantics refer to the business sphere, enrichment is ideally applied by persons representing the business sphere, like business analysts.

Methodologically semantic extension is applied by four different mechanisms (Atkinson, Gerbig, & Fritzsche, 2013):

1. The in-built mechanism refers to the profile mechanism from UML and similar approaches
2. Meta model customization refers to any (ad hoc) alteration of the meta model.
3. Model annotation covers adding extra information or an integration with external models.
4. Multi-level extensions intend to add new vertical abstraction layers for domain concepts.

Amongst literature, authors focus on two types of semantic extension approaches: A) Approaches aim to enrich behavior of a business process. B) Enriching specific Business process domain meaning. Discussed are the most recognized BP languages: Petri Nets, Event Driven Process Chains and the Business Process Management Notation.

Petri Nets for instance are discussed by Koschmider aiming to add domain specific knowledge (Koschmider & Ried, 2005). Another example on extended petri nets is given here: (Brockmans, Ehrig, Koschmider, Oberweis, & Studer, 2006). Adding domain semantics – also in sense of constraints and rules- to BPMN is described by Fanesi, Cacciagrano, and Hinkelmann (2015) and Abramowicz, Filipowska, Kaczmarek, and Kaczmarek (2012). Thomas and Fellmann (2007) discuss how to enrich EPC with semantics, by considering a breakdown into semantic subclasses, as ‘type’. How to utilize semantically annotated EPC for automated modeling purposes is discussed by Bögl et al. (2008). Domain extension exemplification, accompanied by a branch specific case study (health care), is introduced by Braun, Schlieter, Burwitz, and Esswein (2015).

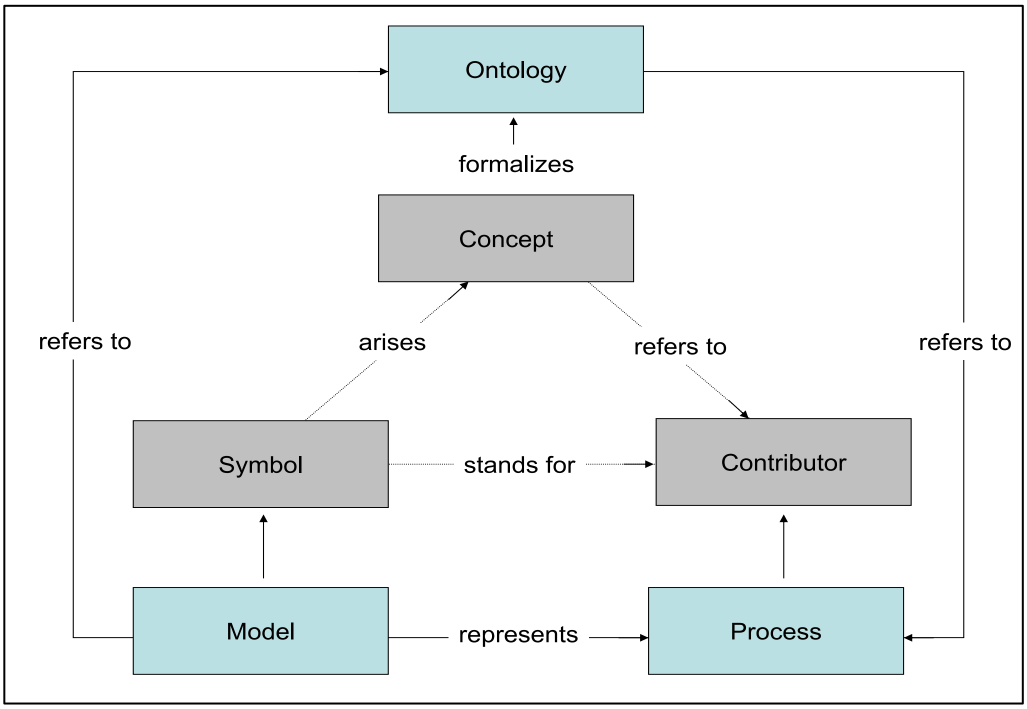

Figure e: Semiotic Triangle funding for Process Semantics and Semantic Extensions.

7.10 Quality Assurance (Type 4)

Among literature dealing with ontologies and frameworks, purposes in a quality assuring aspect are discussed. Quality assurance in a semantic BPM context and for this work is understood as semantics that support process (quality) evaluation e.g. by reasoning, exception and constraint handling. Most often chosen approach is the setup of special purpose ontologies, like the 'business rule ontology', or frameworks that enable quality assurance. Thus, out of a business (logics) view it may be distinct between rules and constraints.

A further major impact on business processes do have legal and regulatory constraints, as well as corporate rules. By applied approaches, it is to distinct along time axis: quality assuring effort that is applied ex ante (validation), or ex post to execution. As another perspective on temporal 'intervention', quality assuring, is to be distinct along phase: During the (ongoing) modeling phase, e.g. by applying semantic enriched modeling validation. In this context, constraints are to be seen, as the aim to ensure restrictions, limitations. They may refer to facile assertion, as ‘every process needs a start and end’, as well as more sophisticated like resource restrictions. The literature corpus does consider solely the second.

While execution, e.g by applying specific (business) rules via ontologies, like the BRO (business rules ontology), or by analyzing and monitoring a specific process. The letter is widely proposed with automated modeling (BPM) updates. Both approaches are equally discussed. Focusing on - upfront to execution - steps of modeling, quality assured procedure is introduced here: (Zhimin Hua, J.Leon Zhao, Veda C. Storey). A domain ontology modeling approach is introduced, that facilitates the conceptual development of a formal approach to facilitate modeling of business processes with an ontological method (Zhimin Hua, J.Leon Zhao, Veda C. Storey).

Quality assurance of BPM models by rule based ontologies is proposed by Thomas and Fellmann (2009). A tool driven validation of models, based on petri nets, is introduced here (Dijkman, Dumas, & Ouyang, 2008). Another tool-based approach on semantic monitoring and analysis is introduced here (Pedrinaci, Lambert, et al., 2008). It focuses integration and derivation of business knowledge out of “low-level audit trails generated by IT systems and thus, explicitly support ontologies.

An approach applying BPM model matching that is semantically supervised is introduced. By using a “language-driven similarity function” human judgment is reproduced (Sonntag et al., 2016). “Meaningful weakness patterns” that are referring to a whole BPM life cycle, is introduced here (Becker, Bergener, Breuker, & Räckers, 2012). The patterns support both semi-automated modeling and analysis.

How to apply and utilize ontological driven (rule) reasoning of the process space is discussed here: (Cabral et al., 2009), or here: (Norton, 2009). Business artefacts interaction to ensure conditions and events are proposed by Hull et al. (2011). By specifying artefacts life cycles in context with “cases” and ECA rules (event-condition-action), “precise, rule-based semantics” are given.

Ontology frameworks for constraints and rules and validation are introduced by Markovic et al. (2008). Cases of incomplete and inconsistence information and how they are to be handled by an ontology is described by a newly set up process ontology is elaborated by Decreus and Poels (2008). A knowledge based security framework for BPM is elaborated (Huang, Yang, & Calmet, 2006).

How via a (semantically enabled) framework, a "compliant" life cycle setup is established, is conceptually schemed here: (Elgammal & Turetken, 2015). Focus on modeling spheres, that need to be integrated is put by Lagos, Vion-Dury, and Mos (2018). By implementing an integration layer that connects business (modeling) space and a corresponding semantic modeling space semantic integration is enabled.

7.11 Automated Synthesis of Process Models (Type 3)

Automated synthesis of business processes is described as an 'advanced' aim of semantically integrated BPM. Ideally, distinct process models are not just integrated semantically, but have the capability to automatically adapt and synthesize in change cases. Simplified, it is close to business reality, that if process A is updated, process B is affected. Affection thereby can be one-way directed, as well as bi- and multidirectional. Thus, the task is to transform models respectively to changes, triggered by business.

Beneficial effect is an automated optimization of business processes, as updates require elsewhere time-consuming manual updates. Wang et al. (2011) present an approach based on 'incremental synchronization of multiple process models by optimizing the information flow'. First, 'multi model synchronization semantics' and its propagation scope are defined. Second, a mathematical model is applied that enables automated synchronization.

Based on calculus and directed graphs is the approach introduces by Lautenbacher. "Machine understandable information" (ontologies) is thereby utilized for automated synthesis: "semantics of each process is compared with the functional semantics of all other processes in a reasoner. The results of these queries are converted to numbers and stored in a synthesis and identity matrix. These matrices are then interpreted as a directed and weighted graph. Based on these graphs the synthesis algorithms can then compute bottom-up what the optimal composition of all processes would look like" (Lautenbacher & Bauer, 2006).

Skouradaki, Andrikopoulos, and Leymann (2016) introduce a method that creates a synthetic executable process model, that follows 'specific structural criteria defined by the application's user'. The method contains four phases: characterization, selection, compatibility and generation, execution and is based on BPMN 2.0.

7.12 Architecture

Studies do refer to the accompanying architecture of a semantic BPM due to the integration idea of combining layers and domains vastly. Most prominent are references referring to a 'service-oriented architecture' (SOA). In the following sections an insight is provided on what is proposed in this context. The service-oriented architecture thereby is described as an appropriate architectonical approach, due to its orientation on business processes abstraction layers and SOA characteristic. It further supports the exchange of (semantic) web services. Therefore it gets preferable for integrational purposes of distinct models and applications (van der Aalst et al., 2000). Amongst literature SOA is described both: as paradigm and as method.

"The dynamic discovery of registered services. This includes searching for services that meet certain criteria, especially business criteria such as delivery time, price, etc. The organization of services, so that one can easily understand what a service offers. The description of services, so that a service can be properly invoked. This includes formats and protocols for invoking the Web service" (Leymann et al., 2002). Thus, BPM is often "combined with the Service Oriented Architecture (SOA) paradigm. Whereas BPM specifies how the organizational resources (including IT resources) are used to achieve the business goals, SOA focuses on the IT architectures that are intended to be conveniently adapted to changing business requirements." (Abramowicz, Fensel, & Frank, 2010).

Amongst literature two main approaches utilizing same technologies (ontologies, lifting), but distinct focal points are:

1. An approach, that focus on linguistic meta modeling and ontological meta modeling ('lifting'): Thereby "different models of the bottom model layer are created corresponding to different metamodels that in turn are created using one common metamodel. With the help of this 'linguistic metamodeling' primarily syntactical but also some semantic aspects of model elements are defined. The basis for semantic interoperability is provided via linking model elements of arbitrary layers of the metamodel hierarchy with ontology concepts. This process is known as lifting or ontology anchoring and fulfills the task of ontological metamodeling" (Höfferer, 2007).

2. A concluded semantic BPM system, including a service bus and semantic layer that acts as a 'brokering service' accompanied with a semantic 'engine' is proposed e.g. by Filipowska, Kaczmarek, et al. (2009).

“This is the foundational layer that deals with brokering service requests from the upper layers. Second, a Semantic Process Engine. This is a process engine that instantiates and executes business process models and handles the related service requests from the service bus. Third, the Semantic Process Modeling Layer. This layer stores models of business processes plus all additionally relevant spheres of the enterprise, e.g. regarding the organization, resources, etc. … a specific reasoner can be used to create a valid control flow from an existing declarative process. Alternatively, an SBPM tool can be used to guide the user in creating a control flow that meets all constraints. The same two options can also be used for exporting “rigid” control flows in the form of BPEL from SBPM models, in order to have them executed by existing workflow engines. Subsets of SBPM models can also be exported as EPCs for the use in existing EPC-based tooling environments.” (Hepp & Roman, 2007).

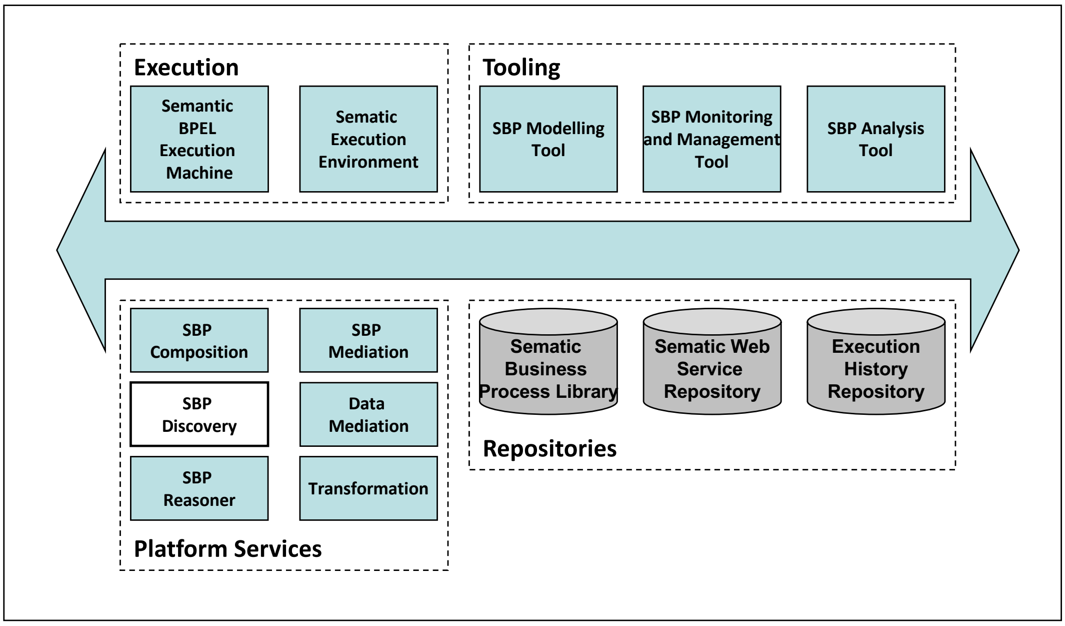

Figure f: Concluded Semantic BPM Service Bus. Modified from Filipowska, Kaczmarek, Starzecka, Stolarski, and Walczak (2008).

Studies do point out architecture related challenges, that arise in context of a semantic integration too. Hinkelmann et al. (2016) for instance claims, in regards of complex enterprise architecture and agility: “machine intelligibility of enterprise architecture descriptions is considered essential for agile enterprises. A machine understandable and interpretable architecture description would allow to answer questions like ‘which processes are affected by the replacement of an application?’, ‘which roles are involved in the process?’’

Further it is noted in regards of SOA and semantic BPM, that distinct perception and understanding of a process due to various actors that are involved in the BPM lifecycle. Thereby the main example of communication difficulties 'is constituted by the business / IT divide (Abramowicz et al., 2010).

7.13 Utilization, Applications & Aims

Since this work is applied out of business perspective, it is the aim to extract and outline overall targets too. Examined literature phrases deeper integration purpose beside clear statements, e.g. Jung (2009), partly narrow shaded, or just implicitly. For instance, "aim for semantic query" may be stated, without precising who the query finally refers to: the modeler, or the operator. If purposes are discussed, most often ascertains on requesting semantic integration, are given by phrasing necessity to "close the gap between the process space of an enterprise, and the actual process space" (Hepp & Roman, 2007). The need to overcome "human interaction" and the lack of "automation" between diverse domains (Woitsch, Karagiannis, et al., 2009).

Besides the claim for reduced human process interference ('automation'), authors state aims that refer to partial or sub aspects of an integrated semantic BPM like automated modeling or increased scalability of Business Process Management (Pedrinaci, Domingue, et al., 2008).

Two studies refer to "cost reduction" as an overall aim, e.g. here (Pedrinaci & Domingue, 2009). Other statements refer to the BPM responsibility and business understanding: "Shifting in control of processes from IT professionals to business natives" and "carrying up BPM to a new complexity level" and provide access to semantics on business level (Filipowska, Hepp, et al., 2009). It practically means, that business experts shall be involved into the modeling process. This aim is also referred as 'shared modeling' (Thomas & Fellmann, 2009).

Semantic use within an "at least semi-automated BPM life cycle" as it would allow "shortening the implementation time and allow increasing the flexibility of enterprises understood as a quick adaptation to changes in business environment" (Filipowska, Hepp, et al., 2009). In use context of ontologies and semantic web services "Goal based" process analysis is stated by Rivera et al. (2008), by further providing a list on why semantic web service are to be utilized in BPM:

1. publication: make available the description of the capability of a service.

2. Discovery: Locate different services suitable for a given task.
3. Selection: Choose the most appropriate services among the available ones.
4. Composition: Combine services to achieve a goal.
5. Mediation: Solve mismatches (data, protocol, process) among the combined, and
6. Execution: Invoke services following programmatic conventions.

Similar different scalability scenarios of web service usage in the semantic BPM context are described by Kerrigan et al. (2009):

1. Using semantic web service for service advertisement
    a. Capability based service advertisement
    b. Mediator-based Service Advertisement
2. Using Semantic Web for service invocation
3. Service Composition
4. Design Tim service composition
5. Engineering Ontologies for describing web services
6. Enabling interoperate ability between ontologies

Last not least, beneficial utilization refers to enforceability of legal and corporate rulings and thus compliance. Process models may be semantically validated and inadequacies detected already during the modeling phase (Thomas & Fellmann, 2009).

7.14 Semantic Business Process Management & the BPM Life Cycle Concept

Since the life cycle concept is the most prominent representative of BPM, in the following paragraphs focus is put on studies explicitly referring to it. Studies that refer to the life cycle, propose semantic BPM as a self-contained system. Impacting aspects are discussed to broad extent and from both IT and Business perspective conceptually (figure g).

Instead of focusing on specific domains. Typically, a stack of impacted ontologies, the architecture and are considered, the environmental architecture is reflected too. Basically, respective overall approaches do not differ from approaches discussing just sequences out of a semantic BPM concept like semantic extension of BPM modeling approach: Specification are lifted via ontologies to a meta model, a process storage is introduced to store information, knowledge is gathered via process incidents and formal input like constraints or specific domain knowledge.

Hoang, Jung, and Tran (2014) describe this approach as “extension as extensive conceptualization of the BPM domain, including various aspects like modeling, composition, execution, and analysis throughout the life cycle of BP”. Agata Filipowska (Filipowska, Hepp, et al., 2009), Branimir Wetzstein (Wetzstein et al., 2007), and Carlos Pedrinaci (Pedrinaci, Domingue, et al., 2008) explicitly refer on the second approach outlined in the architecture section (‘concluded semantic BPM system’), focusing on the business sphere, by claiming the fundamental objective “to raise BPM to the business level where it belongs from the IT level where it mostly resides now” (Born, Drumm, Markovic, & Weber, 2007). Major target is “shifting control of processes from IT professionals to business natives and carrying up BPM to a new complexity level”. Life cycle related focus is put on a conceptual guideline through the distinct phases of a semantic BPM system. Framework for modeling steps, procedures and architectonical set up is introduced.

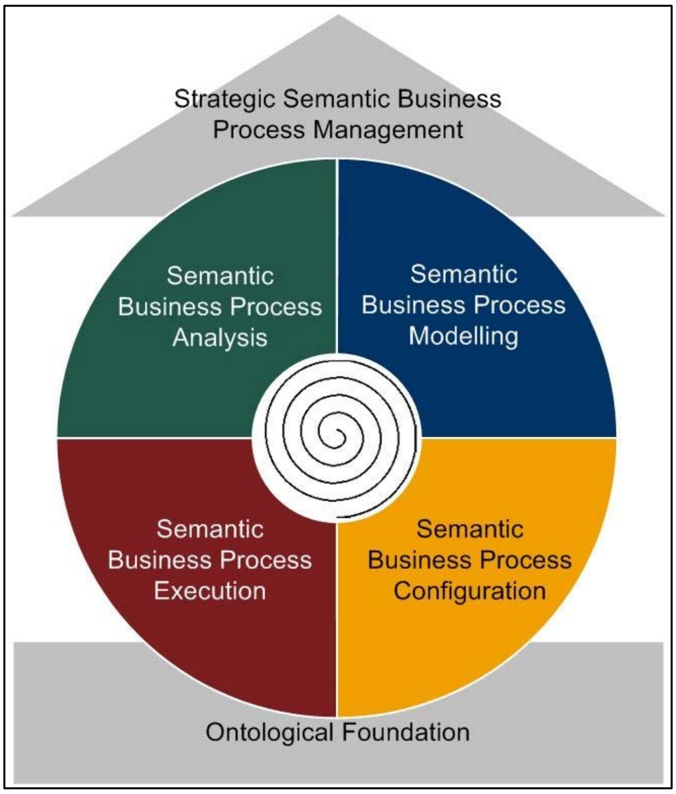

Figure g: Semantic BPM Covering the Life Cycle Concept (Wetzstein et al., 2007).

8 Conclusion

In this work overview and insight on integration of semantics into BPM was provided. Relevant literature, covering the time span 2005 – 2018 is edited and reviewed under the aspect of closing the gap between business and IT sphere. The work thereby is structured out of a business perspective. Clustering refers therefore on business aspects as ‘quality assurance’.

It is found, that vast majority of works have a conceptual and ‘guidance’ characteristic on modeling a semantically integrated BPM environment. Modeling domains are discussed, emphasizing organizational aspects. Thus, methods are given by focusing on (sub) aspects, as notations of organizational ontologies or semantically extension of existing languages. Semantic validation and BPM model synthetization are covered too. Literature further provides proof on operational reliability by various case studies.

Critical remark is to put on the base of examined literature. Aim of this work is to provide overview on research and insight on distinct approaches and aspects. Thereby, delimitation on semantic workflows and the BPM execution phase is floating. Also, scholars tend to refer on ‘business process management’ at the abstract or introduction, without specifying a concrete BPM aspect. By the background of the defined scope, respective studies were rejected.

Studies overall aim is put on ‘automation’, followed by ‘including business experts’ and shifting modeling towards business. Auspicious aspects, as leveraged corporate rules are raised. By the background of increased (internal and external) audits, further emphasize on corporate transparency, enabled by semantic BPM would be a future point of interest. Heterogenous IT landscapes in medium and large sized enterprises lead to ponderous troubleshooting, error descriptions and alignment processes. Besides ‘agility’ and the implicit time oriented ‘decision support’, no time related claims are raised or discussed. In that context further discussion on semantic ‘fault-tolerance’ is of interest too.

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Abstract

This work reviews the integration of Semantic Business Process Management (BPM). Enterprises face in between the organizational, business process management and IT domains lack of semantic understanding. Human integration and alignment between the spheres is mandatorily required. Semantically enriched information exchange is to replaces this requirement. Decision support and automated execution are achieved. Business Process Management (BPM) is a holistic, managerial process concept, that is constitutively and widely used amongst corporates and has effectively proved its capabilities from steering and modeling to executional tasks. BPM is therefore predestinated for IT based, semantic enrichment of business purposes.

First, aspects of the two spheres are discussed that are fundamental for integration. Concept of BPM, and semantic technologies are elaborated. Modeling aspects, like meta model concept are, due to the back-bone characteristic, considered too. Focus is put on organizational (business sphere) and design aspects. Secondly a review is applied, examining research on semantic BPM. Findings are sorted by a set of indices and comprehensive types. Third, findings are introduced and discussed.

Zusammenfassung

Diese Arbeit bespricht die Integration von semantischen Technologien und Geschäftsprozess Management. Unternehmen sind mit einer semantischen Lücke konfrontiert, die sich zwischen IT Sphäre einerseits und Geschäftsprozessen bzw. Geschäftsdomänen andererseits, ergibt. Die Lücke erfordert menschliche Intervention, um Integration und Abstimmung sicher zu stellen. Semantisch angereicherter Informationsaustausch zwischen den Sphären soll die Lücke schließen und Prozesse automatisieren, so wie Entscheidungsfindungen unterstützen.

Das Geschäftsprozess Management ist ein verbreitetes, ganzheitliches Konzept, das für unterschiedliche Aufgabenstellungen von Modellierung bis Ausführung eingesetzt wird. Es ist daher prädestiniert für eine semantische, IT basierte Integration.

Zunächst werden die grundlegenden Aspekte der zwei Sphären vorgestellt und diskutiert. Modellierungs-Aspekte, wie das Meta-Model, werden aufgrund der konstituierenden Charakteristik berücksichtigt. Der Fokus liegt jedoch auf der Geschäfts-Sphäre, so wie dem Design. Darauf aufbauend wird die relevante Literatur untersucht, und nach Typen und Indexes sortiert. Diese Ergebnisse werden abschließend vorgestellt.