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Industry Operations Architecture for Business Process Model Collections

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Abstract. The absence of a holistic industry-centric architecture for processes is an important BPM shortfall that impacts model collections. This paper introduces a *Componentized Industry Business Architecture* as a vehicle to address this gap and to make processes better integrated with other critical dimensions in organizational design. This architecture provides the foundation for a taxonomy of processes and enables process models to be created or potentially rationalized against a comprehensive framework.

Process theory and industrial organization show that processes have different structure and dynamics. However, most processes used in workflows and case management have a similar 'factory' nature, i.e., production processes in the enterprise. This paper shows that not all operations that matter follow this type of behavior. The Componentized Industry Business Architecture brings large families of essential operations to the attention of BPM researchers as targets of modeling. Among these families, *Oversight Processes* constitute an important example and will be studied in depth.

Keywords: Business Process Collections; Industry Operations Architecture; Process Taxonomy; Business Process Management; Organizational Design

1 Introduction

The goal of creating and governing collections of business process models in different industries is central to the success of the life-cycle addressed by Business Process Management (BPM). The broad application of process modeling has stimulated contemporary organizations to create many process models in support of their operations [1], [2]. In fact, a single line-of-business in a large enterprise typically has several hundred key processes. With such large collections of process models, an apparent issue is how to sensibly deal with them, in particular when considering that models should be consulted, updated, and re-used over long periods of time by various stakeholders [3]. Other challenges for process model collections stem from broader issues with BPM [4].

In an extensive and seminal investigation, [5] proposed to "*reduce the confusion"* (sic) by distinguishing between three meanings of process, namely, (1) a logic that explains a causal relationship between independent and dependent variables, (2) a category of concepts of variables that refers to actions of individuals or organizations, and (3) a sequence of events that describes how things change over time. In fact, Van de Ven's work went beyond merely defining a process and addressed these concepts in the context of one of the most complex and critical types of processes in organizations, i.e., the strategy process. The depth of Van de Ven's classification reveals the foundations underlying most business process definitions in BPM. In spite of having been published almost two decades ago, this work from well-known social science researchers has gone unnoticed in most of the BPM review literature and books.

Even though workflow and process modeling have been used extensively over the past 30 years, surprisingly little is known about the act of modeling and which factors contribute to a "good" process model in terms of human understandability [6]. To guarantee a certain degree of design quality of the model artifact in a wider sense, several authors propose guidelines for the act of modeling [1], [7] but yet with little impact on modeling practice. Also, typical information technology issues arise [3], [8], [9], [10], [11] in managing large collections of processes.

This paper introduces a componentized architecture of business operations based on two important dimensions in organization design: competences and resource hierarchies. This concept realizes the principle of resource aggregation from Penrose, complexity reduction from Simon and related work from different organizational research schools, thus yielding a *componentized* or *modularized approach to industry operations.* This comprehensive architecture helps organize processes in model collections by adding key aspects of organizational design that matter to the semantics of operational behavior models and covering family of operations beyond those addressed by conventional BPM work. In fact, new *subjects* of operations modeling are introduced in Section 2.2 through the notion of *ensembles of entity instances*. This family builds beyond "factory" processes that have been the main focus of BPM and Case Management. The dynamics of these *subjects* represents a family of enterprise operations called *Oversight Processes*. *Oversight processes* constitute an outstanding example of the comprehensive process taxonomy introduced in this Section.

2 Process Architecture and Taxonomy for Model Collections: Behavior in the wider context of organizational design

Process model collections require an adequate architecture that explains the structure of processes and a related taxonomy that helps categorize process models according to what an enterprise is and expects to accomplish with these models. A framework for processes (i.e., an architecture and related taxonomy) should shed light on what operations process models intend to represent and how these representations relate to industries and organizations.

Processes are about the behavior of an organization. This behavior is inseparable from the rest of the constituent elements and attributes of the organization, its goals, capabilities, outcomes (i.e., products, services and related value-propositions), industry segment position, skills and resources in general [12]. Section 2.1 introduces the concept of *Componentized Industry Business Architecture* to model the business from a broader perspective angle than processes. The Componentized Industry Business Architecture is holistic in the sense that it helps fit behavioral models within the broader scope of organizational design and does so by also modularizing business operations. This architecture approach is related to the classical notion of business architecture but it has several distinctive features as will be seen later in this Section.

An important example of the way the taxonomy derived from Componentized Industry Business Architecture widens the perspective on processes is illustrated by *Oversight Processes.* This family of processes goes beyond "factory" operations and is investigated in depth in Section 2.2. The relationship between *behavior* and *subject* of the model is an important foundational dimension of oversight processes. In fact, this relationship builds on a more general liaison between process and subject (at times also called *entity*) cultivated for a long time in both social and information sciences. The linkages between behavioral and entity models developed mostly at the realm of the European schools constitute a body of essential, practical and inspirational outcomes [4] surprisingly unnoticed in most of the BPM literature.

2.1 Componentized Industry Business Architecture

Defining the boundaries of a process and the main stages that define its progression are key activities in operations modeling. There are many techniques documented in the BPM literature that tackle these objectives, involving a wide variety of methods [13] and standards [14], such as those based on goals [15], functional and activity-centric [16], Role-Activity Diagrams [17], communication-based [18], workflow-centric [19], based on Petri Nets [20], case-based [21], Event Process Chains [22], and so on. Telling from the difficulty to harvest and reuse found in the existing art of process model collections, it would be reasonable to argue that modeling methods have not been very successful in capturing *semantics of business operations.* These semantics should not be understood only as *clarity* or *understandability* but also as a *language of business design* that goes beyond the description of behavior.

Designing business operations holistically is a complex problem and thus, it benefits from a modular architecture. Modularization is a good approach to tackle complex problems [23]. The basic goal of *decomposability* and *near-decomposability* is to *manage complexity* of a system by reducing the number of distinct elements and grouping them into a smaller number of subsystems. Business applications of some componentization ideas have been found in the financial services industry in [24] [1]. However, none of these works has been rooted into seminal concepts from resource-based view of the firm, resource hierarchies or related industrial organization research. Instead, harvesting from hundreds of practical experiences has been linked to those from other domains, including Service Oriented Architecture and BPM, paving some simplified and practical ideas to make business architecture a more actionable concept in support of the convergence of strategy, operations and information technology [25].

On the other hand, several schools of thought working on theories of the firm state that *resources come in bundles* and argue that resource endowment and continued development of idiosyncratic capabilities by an organization build the foundations of competitive differentiation and sustained performance. These subjects lie at the heart of organizational design and related theories and thus, they go beyond the goal of this paper. It is enough for the purpose of this Section to stress that none of the strategy management schools, particularly the so-called "*resource-based view*", have proposed any specific design principle by which the aggregation of the resource hierarchy manifests in practice and leads to a model of enterprises or industries. In this sense, the paper goes a long way by making some foundations of the theory of the firm into a reusable body of work. As an important byproduct, the *componentization* proposed and its underlying architectural elements provide an important taxonomy to address process model collections within an ambitious and broad economy of scale and reuse.

The aggregation of resources according to selected design criteria is a viable way to generate such modularizations and consequently, a componentized architecture of the enterprise. Furthermore, if the aggregation principle is suitably chosen, industry variation can also be incorporated. In order to discuss the design principle, it is necessary to understand that the concept of resource used in the context of organizational design is not limited to physical assets or people. Enterprises are endowed with and also generate a variety of resources that form a hierarchy in terms of the degree of elaboration or entanglement required. By simplifying the resource hierarchy and also following [26] and other colleagues

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[1] These patents are available in the public domain and may be accessed through different conventional channels.

from the competence-based theory of firms, it is possible to keep the hierarchy to 4 levels as shown in Figure 1.

The distinction across these levels is relevant to demonstrate that important activities in an enterprise involve more elaborated constructs than the typical "resource" concept used in BPM and Case Management. Thus, when reference is made to "a bundle of resources" in modularization language, the notion includes these richer constructs of Figure 1. The highest levels in this hierarchy, i.e., skills and capabilities, may be found troublesome by computer scientists and information engineers probably more accustomed to the *input-output* mechanism of production processes by which resources are inputs consumed by tasks to produce outputs. *Information,* viewed as a resource in the hierarchy of Figure 1, should be regarded specifically as an *asset*. The interested reader is referred to the extensive and rich literature spanning three decades of research work on capabilities, dynamic capabilities, resource-view and competence-view of the firm for a deeper dive into these concepts [27], [28], [29], among many others.

In fact, the resource hierarchy goes further up from the *capability level* shown in Figure 1 to include also the concept of *competence* and often *core-competence* as well. The notion of *competence* is also used in this design principle to segment the entire enterprise resources into disjoint families. Each competence clusters all significant resources necessary for those specific enterprise activities in direct support of the life-cycle of the competence. Obviously, there are a number of competences and some of them vary across industries. For example, *Upstream Operation* is a competence of a typical oil and gas industry; *Water Procurement* is a competence in the water segment of the utilities industry; *Health Care* and *Environment* are competences in the city government segment of the public industry; *Customer Service* is a typical competence where services matter and thus, it takes place in a variety of industry segments such as banking and telecommunications; and so on.

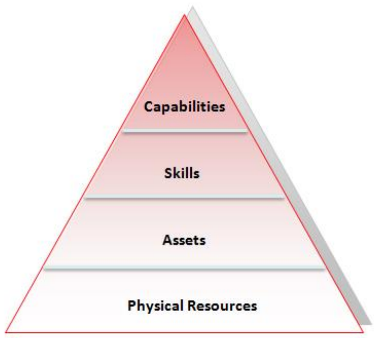

Figure 1: Elements of the Resource Hierarchy involved in the architecture

The other aspect of the modularization is based on a typology of the enterprise activities in which resources are also used. This dimension leads to a partition of resources into four levels, as seen in Figure 2. These levels correspond to four broad categories of activities involved in creating a wide but still well-differentiated variety of outcomes such as those arising in *vision and strategy*, *learning and innovation, oversight and management,* and *production and maintenance* operations. This hierarchical arrangement builds upon the work of Chandler [30], [31] among several others.

The combination of both aspects above yields a partition of the resource space that is the foundation of the modularization sought. The two dimensional arrangement of this modularization is shown in the layout of Figure 3. A refinement of the main modules may be needed for more detailed description and can be obtained by further partitioning those resources and activities that are needed to produce the different outcomes corresponding to the intersection of each column (i.e., competence) with each row (i.e., a level of hierarchy from Figure 2). In this figure, there are two such partitions shown with four components each, where Component X and Component Y have been highlighted for illustrative purposes.

By using the design principles above, a Componentized Business Architecture has been built for many industry segments, including banking, insurance, oil, chemicals, pharmaceutical, retail, consumer package, telecommunications, different government sectors, health care, automotive, industrial electronics, energy, water, heavy equipment manufacturing, avionics, transportation, to name a few important ones. Typical scenarios in practice have yielded industry architectures having anywhere between 80 and 150 business components. [25]. In some cases, the underlying structure has been simplified a bit further by collapsing the middle two layers of the hierarchy of Figure 2 into a single one. As an example, a much simplified architecture for the City Government industry segment is shown in Figure 4, which follows the jargon introduced in [24]. In this case, there are 11 competences while the oversight and learning layers have been integrated into one, called “control” (the Government industry tends to have more oversight operations than learning or innovation activities). The complete model based on this architecture has over 150 business components representing the wide gamut of operations that City Governments may have.

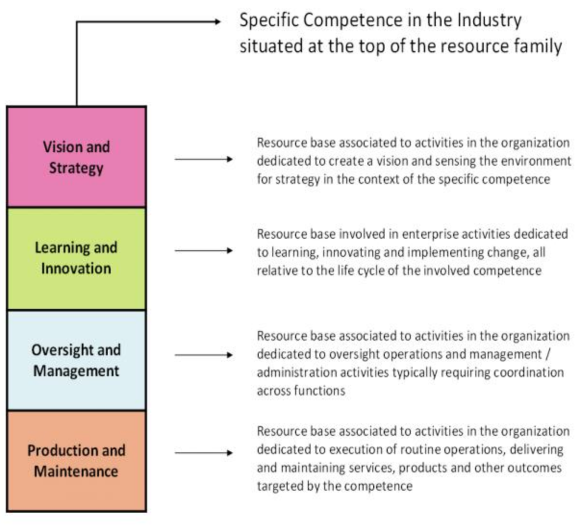

Figure 2: Aggregation of resources for a given competence into hierarchical levels

A feature-by-design of the Componentized Business Architecture is that business operations encapsulated by a component are characterized by having the same level of responsibility or accountability (in the sense of the hierarchy shown in Figure 2) and being dedicated to the same specific competence in the enterprise. There is a “provisioning chain” view implicit in this business componentization since *outcomes* from a component explain the reason for the resources to be bundled, i.e., to support the creation of entangled and specific value-propositions in the component. These value-propositions justify the existence of the business component as a true aggregate, albeit virtual, and not only as an architecture artifact. Perhaps, business outcome is a better upper ontological term.

Obviously, the componentized architecture includes more detail than descriptions of industry / cross-industry competences and business components. Each business component contains the specific resources bundled, including capabilities, skills and roles playing them in the organization, performance measures, assets, other intangibles and physical resources. Furthermore, every business component contains individual *activities* (i.e., the behavioral side of the architecture) using these resources and supporting their evolution. Typical industry architectures include in the order of 10 to 20 activities per business component.

On the other hand, the dependencies across business components are what make the architecture of the business being modeled come together in one place. While specialization of the operations encapsulated in a component and localization of the resources that support the corresponding activities guarantee a weak coupling, interaction across components do exist. This subject bears an intimate connection to the study of organizations as governance and thus, it goes beyond the goal of this paper. These forms of collaboration should not be confused with *value-streams* and other *end-to-end processes* that compose behavior from different components in supporting certain critical capabilities. There is no analogy intended or recommended with respect to the conventional notion of "service orientation" from computer science.

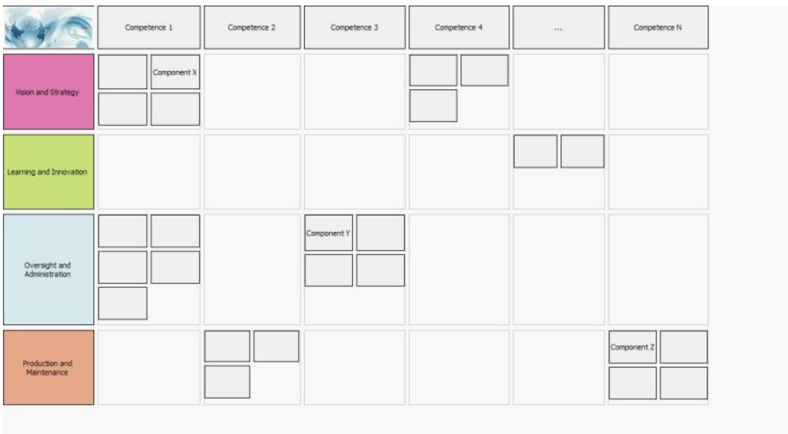

Figure 3: Componentized Industry Business Architecture – A simplified view with a few competences and components highlighted

The Componentized Business Architecture principles discussed above can be applied *verbatim* to finer-grain organization design such as Line-of-Business (LOBs) or departmental units.

In principle, the same concepts can be recursively used to go into more detail from the enterprise or industry level. For example, the business operations encapsulated in one component can also be modularized. To this end, the hierarchy of resources should be repeated within the scope of the business component or LOB[2].

Likewise, competences should also be contextualized to fit the organization domain being modeled.

[2] This means that the concepts of *strategy, vision, oversight, management, execution, administration* and others in Figure 2 need to be contextualized for the specific business component, Line-of-Business or organization being architected.

	City Strategy & Governance	Public Safety	Transportation	Citizen Health	Energy & Water	Environmental Sustainability	Urban Planning & Building Management	Economic Development	Social Services	Education, Culture & Recreation	Municipal Administration
Direct	City Vision and Strategy	Public Safety Strategy	City Transportation Strategy	Citizen Health Strategy	City Utilities Strategy	Eco-City Strategy	Urban Planning Strategy	City Economic Policies	Social Services Strategy	Education and Culture Policies	Government-wide Administration Strategy
Control	City Performance Management	Crime, Fire and Emergency Management	Transportation Service Management	Health Service Management	Utilities Service Management	Sustainability Programs Management	Development and Permit Management	Economic Programs Management	Social Programs Management	Education and Culture Programs Management	Administration Services Management
Execute	City Governance Operations	Public Safety Operations	Transportation Infrastructure Operations	Health Service Operations	Utilities Infrastructure Operations	Sustainability Programs Delivery	Land and Buildings Operations	Economic Development Operations	Social Services Delivery	Education and Culture Operations	Administration Services Delivery

Figure 4: A simplified view of Componentized Business Architecture for the City Government Industry. The middle two layers of the hierarchy of Figure 3 have been collapsed into a single one due to the nature of this industry segment

This has been done in real practice for different business components and entire LOBs such as Finance and Accounting, Human Resources, Information Technology department, and so on. The number of business components, competences and activities is similar in these finer-grain architectures. This means that collecting the content from 10 typical LOBs in an industry, a total of approximately 1,000 business components and 10,000 activities is produced, among several other elements of the architecture such as capabilities and resources.

The Componentized Industry Business Architecture is a comprehensive concept in the sense that it goes beyond processes while fitting behavioral models within the broader scope of organizational design. The architectural elements and their relationships provide a modularized framework for integrating process models with the realm of other modeling domains in enterprise operations. The derived taxonomy for process classification is a helpful guidance to structure and organize process models. Processes can be overlaid against an extensive model of industry operations that represents all known forms of operations [3].

2.2 Operations Modeling beyond Factory Processes

The modeling of processes in BPM has been greatly influenced by information engineering and computer science concepts. In particular, a model hinges around a number of entities whose behaviors are described. Each entity represents an abstraction as “a class of things” that will find many specific *instances* in the real-world. The same pattern of behavior is expected in the organization when dealing with each occurrence of these instances. Typical examples are *purchase orders, customer complaints, payment requests, account opening*, and so on. Thus, efforts invested in modeling and optimizing operations pay back as a consequence of the resulting processes being used over and over again. The cost incurred in discovering and deploying the best possible process is somehow “amortized” across the many instances for which such a process will be repeated or reused. The repetitious and predicted behavior of the enterprise operations targeted by the

[3] This framework goes deeper than known propositions such as the Process Classification Framework (PCF) (see www.apqc.org).

modeling effort is the origin of the term “factory” [4]. All processes commonly modeled in the literature as workflows and cases are of this nature and consequently, their main goal is efficiency, i.e., time and cost reduction. The amortization principle is thus fully consistent with the term “factory”.

While “the factory” is a critical part of an organization, by no means is it the only form of operation that matters and thus, other models are necessary beyond production processes. In summary, the variety of real-life processes in organizations calls for a close reexamination of modeling, particularly in the light of the assumptions made by many computer scientists that implicitly circumscribe the real-world being modeled to a fraction of the world that organizations face. The purpose of this section is to dive deeper into the structure of a family of processes corresponding to the *Oversight* level introduced in Section 2.1. These processes are very important in actual operations and their modeling is also interesting as a research topic.

Specifically, the “subjects” in the model come in the form of *ensembles of entity instances* but they may not be adequately modeled by entity types in the traditional information engineering sense. An example of this new category is given by the *pipeline of drug compounds* managed in a typical enterprise from the pharmaceutical industry. This pipeline is uninteresting from the information-centric perspective of “instance” because the *pipeline* of compounds is *unique* and not “a class of things” with many instances. It is clear that there is a single “thing” in a company called *pipeline* and not many “instances” of a generic type. Another such an operation is packaging and shipping orders for clients in the distribution industry. The decision-making in these operations belongs to a sphere of behavior modeling conceptually distinct from those activities found in any individual order being processed. This *ensemble of orders* reflects the need for specialized behavior in the organization whose modeling is also critical. Again, like in the case of *pipeline* there is a single “thing” in the enterprise called the ensemble of all customer orders. *Oversight processes are critical because decision-making necessary to successfully progress each individual instance requires the ability to manage properties of the ensemble*.

In the business literature, it is common to find oversight processes loosely referred to as *management processes* [5]. These processes are definitely not new in enterprises but they are rarely discussed by computer scientists, BPM designers, or information systems practitioners (see [32] and the work done on the analysis and application of Viable Systems Model [33]).

Oversight processes have a different structure from that of factory operations and thus, their modeling is substantially more subtle. In particular, it is not clear that the associated ensembles exhibit any interesting life cycle, i.e., one that truly represents the substantial evolution of the entity. A conventional life cycle model depicts the change in an entity as it progresses through a necessary sequence of

[4] In [18], these processes are called “production processes”. Harrison-Broninski correctly argues that case handling is not less factory-oriented than system-centric processes (i.e., workflows). Even if cases do include people intuition or judgment in decision-making, their participation is focused on individual steps of a pre-established routine business process.

[5] *Oversight* is a much preferred term because “management” is a heavily overloaded word. On the other hand, the concept of *coordination* across a variety of functions in the organization represents a type of process that suits management in the *administrative* sense implied by the language of Figure 2. This subject has also been addressed in [33]. Ould calls “management processes” to a concept that is related to oversight processes. However, the taxonomy in this Section builds well-beyond behavior and is rooted into broader organizational design concerns driven by industry business architecture principles.

stages. This progression is immanent, i.e., the lifetime or "fate" is encoded with the very birth of each instance of the entity. There is no obvious, predetermined sequence of activities in an oversight process but a continuous "discovery" of conditions that may affect the well-being of the ensemble. This kind of behavior does not entirely follow the concept of life-cycle but does not disprove it either, i.e., oversight processes call for a complementary concept that leads to a *constructive model* in which development of the subject is purposeful and teleological. Oversight processes clearly require a modeling of the real-world that allows for potential reformulation and variation of the core subject. This should not be surprising since there are other types of processes in practice whose study has required different theories, or combinations not limited to life cycle, such as the strategy processes work documented in [5]. Another fundamental and very simple difference in the dynamics of an oversight process is that the development of the underlying entity does not imply a progression from "birth to death". For example, the pipeline ensemble never dies or ceases to exist and in fact, related organizational behavior aims to make the pipeline stay away from any chance of being exhausted.

2.3 Processes Taxonomy in the Context of Industry Architecture

The evolution toward a process taxonomy derives directly from the proposed Componentized Business Architecture for an industry or Line-of-Business (LOB). Every process in an enterprise should then ideally fall either within one of the following categories or be constructed from scratch to fit one of these categories as a best-practice or guidance:

- Process is entirely contained within one of the 1,000 or so highest-level activities of the architecture
- Process spans more than one of such activities in a single business component of the architecture
- Process requires different activities or behavior therein from two or more business components

As an example, Figure 5 shows a process being composed of activities from different components, at different competences and resource levels [6]. Unquestionably, the availability of a well-designed architecture framework supports modeling guidelines that are more robust than leaving them up to analysts or experts. The latter leads inevitably to idiosyncratic process decompositions, performance metrics rediscovered under new language, new capabilities outside of the as-is architecture or beyond the organizational strategy to create them, and other "favorite" approaches to the classification and modeling of processes. As the proposed architecture is not just behavioral but also contains intentional aspects of the organization as well as capabilities, skills, performance

[6] These scenarios describe the "happy path", i.e., processes designed from scratch. Dealing with legacy processes requires a more involved reconciliation mechanism. This reconciliation makes the componentized industry business architecture become a front-end for process knowledge organization. In some cases, this reconciliation may require reengineering of some processes before they can be made part of a reusable base. Several practical cases have been worked out. For example, existing industry frameworks like PCF have been reconciled with the componentized business architecture of the corresponding industry. These subjects will not be addressed in this paper due to space constrains.

metrics, roles and resources at a minimum, then process modeling is linked to the description of these elements of the architecture.

Finally, another critical topic to bear in mind in process model collections is that certain industries have gone through attempts of creating taxonomies or have such taxonomies already. Some industries have a rich experience accumulated through several years of inter-company collaboration and work in this direction. The hurdle is that these efforts hinge on purely functional principles, i.e., action separated from *resource hierarchy* and taxonomies based broadly on decompositions whose rationale is thus difficult to explain beyond a *fait-accompli.*

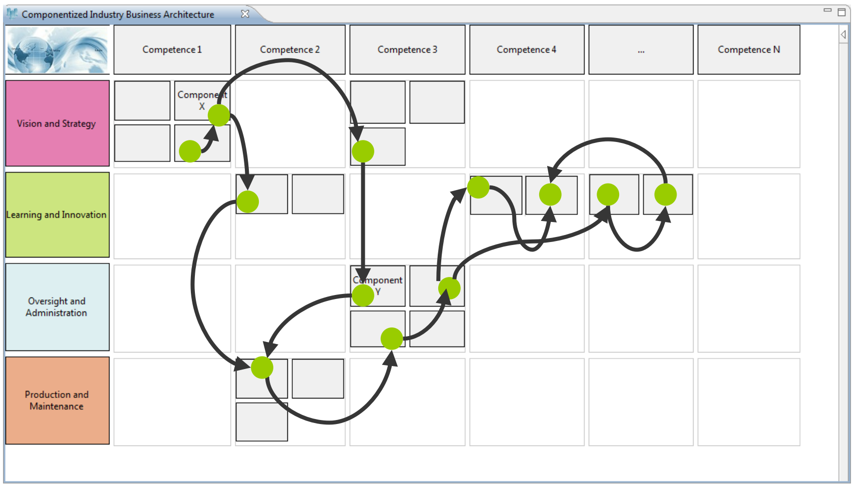

Figure 5: A process combining resources from different components in the industry business architecture. Green dots indicate behavior contained in an activity of the corresponding business component. Arrows are indicative of partial order.

Specifically, taxonomies such as the Extended Telecom Operations Map (eTOM) in the telecommunications industry, SCOR in the supply-chain LOB, Process Classification Framework (PCF) and related industry-specific extensions bring additional challenges as they are not based on any known architecture principle. Furthermore, they do not provide any design guideline to dive into levels below the entire enterprise operations. In spite of that, these frameworks provide very valuable glossary and decompositions that inform the componentized business architecture for the same industries. In closing this Section, it is worth remarking that the main concepts presented above have been taken to a substantial level of formalization in most of their salient aspects.

4. Conclusions

This paper presented an architecture and taxonomy that anchor process model collections in the wider context of organizational design. This context is important in a number of ways. First, it provides a framework for approaching process modeling within the adequate context of activities, competences, resources, information and performance indicators with which an organization operates. The content available from such broader models is much more than a “glossary” or “business language”: it follows a formal business architecture-based view of the organization. On the other hand, the liaison between behavioral modeling and the rest of the architecture of the organization is essential because the intentional, performative, functional and resource dimensions bound and guide the modeling of behavior. In short, process models do not live in isolation and the Componentized Industry Business Architecture provides an ambitious mechanism to accomplish the needed integration across different modeling domains. An important illustration of the value of this context is that large families of operations missing in the context of conventional BPM matter to the correct categorization of behavioral models. This point has been extensively illustrated through oversight processes.

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