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CAPTURING BUSINESS STRATEGY AND VALUE IN ENTERPRISE ARCHITECTURE TO SUPPORT PORTFOLIO VALUATION

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***Abstract*— This paper investigates and enhances the suitability of the ArchiMate enterprise architecture modeling language to support the modeling of business strategy concepts and architecture-based approaches to IT portfolio valuation. It gives an overview of existing strategy and valuation concepts and methods in the literature and motivates the need for enterprise architecture and business requirements modeling to capture these aspects as well. This overview results in the identification of strategy and value related concepts, such as value, risks, resources, capabilities, competencies and constraints. The paper provides an analysis of the extent to which ArchiMate may support some of the above-mentioned concepts and extends it with the missing concepts. The proposed language extension is formalized in terms of a metamodel fragment, which is aligned with the ArchiMate metamodel. The approach is also illustrated by means of an application portfolio consolidation case study in which we demonstrate how a constrained optimization valuation method can be applied to architecture models enhanced with the new concepts.**

Keywords: ArchiMate, business strategy, application portfolio valuation, enterprise architecture, business requirements management, business value.

I. INTRODUCTION

Strategic alignment, architecture alignment and business-IT alignment are some of the many types of alignment problems being discussed and investigated over the past years. The need for alignment arises when distinct disciplines influence each other and their coordination is required to achieve certain goals. For example, when IT is considered to be an enabler of new business opportunities, their successful exploitation depends on how well business and IT strategies are coordinated.

This paper focuses on the alignment of business strategy, business requirements management, enterprise architecture (EA), and portfolio management. Fig. 1 illustrates the interrelationships between these disciplines. As motivated in [25], and explained later on in this paper, coordination of these disciplines is needed in order to be able to align an organization's business strategy with its tactics and operations, i.e., with its projects and EA, respectively. The business strategy describes, in terms of strategic goals, resources, competencies and capabilities, where an organization wants to be in the future. Business requirements management translates the strategy into more fine-grained goals and requirements that form the first step towards the definition of a tactical and operational planning. Some of these goals and requirements are to be realized by architecture elements, while others are imposed on projects and programs. Thus, goals and requirements describe indirectly the contribution of EA and of Projects and Programs to the organization's strategy (as represented by the dashed arrows). More concretely, EA describes the contribution of IT artifacts, such as software services and applications, to the business processes, services and products of the organization, i.e., the "operations", while the Projects and Programs capture the tactic the organization plans to pursue in order to achieve its strategy.

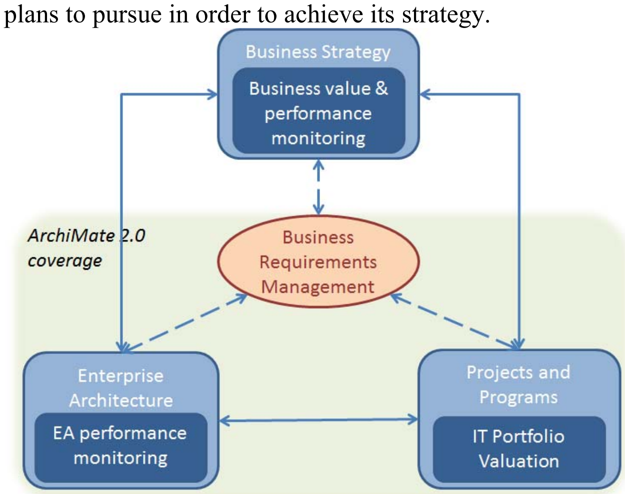

Fig. 1. Influence relationships between our fields of interest

In each of the three disciplines the planning phase is very important. However, the continuous monitoring and assessment of the implementation of these plans against the goals set is equally important: it gives both an indication of the extent to which the planned strategy is realized and it also checks whether this implementation has indeed **value** for the business. In each of these disciplines, methods and techniques exists for performance and valuation monitoring

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and assessment (e.g., the Balance Scorecard [19] is a business performance monitoring approach for business strategy, IT portfolio management for the valuation of projects and programs [1][7][27][28][31][32][34], and performance and cost analysis techniques for EA [14]), Since the output of some of these techniques may constitute the input for others, they should not be used in isolation, but they should be aligned. We argue that this alignment can be achieved through the alignment of the models that are used to describe the concerns of the three disciplines (as depicted in Fig. 1). As a language to express these models we use ArchiMate®, the open international standard for enterprise architecture modeling maintained by The Open Group. The recently published ArchiMate 2.0 standard includes two extensions: (i) the Motivation extension, for modeling the motivation of an enterprise architecture in terms of stakeholders, their goals, principles, requirements and constraints, and (ii) the Implementation and Migration extension, for modeling the implementation of an enterprise architecture and the associated migration from the 'as is' (baseline) to a 'to be' (target) situation in terms of plateaus, gaps, programs and projects. This means that ArchiMate 2.0 supports the modeling of the motivation and implementation aspects of enterprise architecture, in addition to the aspects of information, behavior and structure that were covered by version 1.0 [17] (the coverage of ArchiMate 2.0 is shown in Fig. 1).

However, the modeling of strategic and valuation aspects, such as value, capabilities, resources, and risks, has not been considered explicitly in the work on ArchiMate 2.0. Covering these aspects is needed in order to describe and analyze the business value of IT artifacts and IT projects, and relate it to the business strategy. Therefore, the goal and contribution of this paper is threefold.

First, we aim to identify what concepts are needed to model strategic and value-related aspects in architecture-based approaches.

Second, we want to investigate how ArchiMate can support the modeling of these aspects, preferably by using existing concepts, and otherwise by extending it with a set of new concepts. At this point, it is important to recall the main purpose of ArchiMate: the integration of different architectural domains. This means that various architectural aspects need to be covered by the language, while focusing on the relationships among these aspects. Meanwhile, the language should be kept as concise as possible, by providing concepts only to describe the essential aspects of the architectural domains, and their relationships. Consequently, the introduction of new concepts should be considered carefully and only be done when absolutely necessary. The new concepts will be grouped into a language fragment that is aligned with and extends ArchiMate.

Third, we want to demonstrate how portfolio management and valuation techniques can be aligned and applied to enterprise architecture models expressed in ArchiMate with the proposed additional concepts.

The paper is structured as follows. Section II gives an overview of existing business strategy and IT valuation approaches, and identifies the concepts underlying these approaches. Section III introduces ArchiMate 2.0 and examines to what extent ArchiMate can support strategy and valuation concepts. Section IV proposes the new modeling language fragment and aligns it with ArchiMate. Section V illustrates the use of the proposed extension by means of a case study concerning the consolidation of an application portfolio of a large European energy supplier, and demonstrates the model-based application of a constrained optimization portfolio management approach. Finally, section VI concludes our paper and give some pointers to future work.

II. BUSINESS STRATEGY AND IT PORTFOLIO VALUATION TECHNIQUES

As explained in the introduction, we aim to identify the concepts that capture business strategy and value. To this purpose, we have examined the business strategy and portfolio management literature. We have tried to be as comprehensive as possible when enumerating the concepts we found in the above mentioned literature. In the sequel, we summarize our most important findings in the form of a short survey and an inventory of all encountered concepts included in Table 1.

Project selection is commonly understood as the process of assessing a given set of formal project proposals with respect to one or more strategic goals and deciding to select one (or more) of the proposals that may optimally achieve those goals and initiate it. In this paper a project is defined as a distinguishable and separately funded enterprise architecture change. An IT project portfolio is defined as a set of on-going projects in the organization at a given time or considered for a future period, and which are meant to implement its strategy. Selection models (or techniques) are management instruments used to valuate IT projects according to some given criteria, compare them and decide about their acceptance or rejection. Usually, a selection model tends to be associated with a "mathematical model", while a selection technique is used with the broader meaning of any analytic instrument that may be of assistance during the selection process.

In addition to profit maximization, the strategic goals on the basis of which IT projects are valued and the selection is made are often more than one. Decision makers usually value IT projects in terms of monetary aspects, inherent risk and uncertainty, business benefit contribution, resource utilization, other non-monetary aspects, organizational learning, development of new capabilities and competencies, etc.

Based on the IT project valuation literature, we distinguish between the following main classes of selection models:

Financial and Economic Models, e.g., [3][27]; Constrained Optimization Models, e.g., [1][32]; Multi-criteria Decision Making Models, e.g., [7][33][35]; Checklists, Scoring models, and Relevance Trees, e.g., [8][28]; Architecture-based portfolio valuation, [25]. These classes are neither mutually exclusive, nor exhaustive. However, they are representative enough to support us in the process of identifying and extracting the main valuation concepts. The perspective taken in the above literature is to measure the contribution (i.e., value) of projects to business strategy [9]. To ensure that we do not miss important strategy-related concepts, we have complemented the above literature with strategic management literature [2][4][19][29], which takes the exact opposite perspective, i.e., it sets the goals and critical performance indicators for the projects implementing the strategy. We have selected some of the most well-known theories in this area, the resource-based view of the firm [2][4], the dynamic capability theory [29], and the widely accepted strategic business performance monitoring method – the Balanced Scorecard [19].

To summarize, the examination of the literature lead us to the list of concepts presented in Table 1. Please note that we will deal in Sections III.D and IV with the question whether all the identified concepts can and must be supported by architecture models, and subsequently by an architecture description language such as ArchiMate.

Construct name	**Definition, Remarks**
Value (KPI) (all valuation methods e.g., [19][25], business model frameworks [22], value modeling [12]	Definitions vary from soft/qualitative to formal/quantitative: as objective functions, (economic) indices. Some value taxonomies/frameworks are mentioned: e.g.,[31]. It seems that the concept of value is very much related to performance, since performance measures (i.e., so-called key performance indicators) are also value measures, (e.g., costs, profit, customer satisfaction, etc.).
Value exchange [12]	It represents one or more potential trades of value between two actors. This type of relationship introduced in [12] captures the dynamic aspects of value exchanges by making explicit the value streams between the different actors in a business network.
Cost (of project) [26]	Is a type of value; It has quantitative definitions, mostly expressed in monetary measures. Represents the quantity of a certain resource needed for a project/activity. Cost is also very much related to value.
Resource (allocated to a project) Mentioned in both all valuation methods (quite important in the optimization models, e.g., [1]) and in the strategic management literature. [2] [4] [19]	Defined formally in constrained optimization models and somewhat softer in other models. Could be monetary, people, information resources etc. There is no clear difference between the concept of resource utilization and cost. It seems though that resource utilization could be seen as a broader concept than costs, since resources may also be other than monetary. [13] distinguishes between resources and capabilities and provides a classification of resources into tangible (financial capital and the physical assets, e.g. plant, equipment, raw materials), intangible (reputation, brand image, product quality), and personnel-based resources (technical know-how, other knowledge assets including organizational culture, employee training, loyalty, etc.).
Competence The core competence concept was introduced by [23]	A core competence is a particular strength of an organization. "Core competencies are the collective learning in organizations, and involve how to coordinate diverse production skills and integrate multiple streams of technologies." Examples of core competencies include technical/subject matter know-how, a reliable process and/or close relationships with customers and suppliers.
Capability [2][29]	According to [29] [2], capabilities refer to an organization's ability to appropriately assemble, adapt, integrate, reconfigure and deploy valued resources, usually, in combination or co-presence.
Constraint [1][32][7][33][35]	Limitation imposed on resource utilization. Typical for constraint optimization models.
Risk (of project) Mentioned by most models. Prominent in index models. [8]	Risk the probable frequency and probable magnitude of future loss. It is closely related to goals, since many (business) goals aim to minimize risks. This definition was adopted by The Open Group.[30]
Goal (soft, hard)	Maximization/obtaining/achievement of some kind of qualitative or quantitative (business) value or minimization of costs/risks. Goals are prominent in all valuation methods, strategic management and goal modeling languages (e.g., I* [34], Tropos [5], KAOS [20]).
Goal hierarchy Architecture based valuation, relevance trees, goal modeling languages	Refinement and structuring of goals. It mostly goes from high-level abstract and soft goals to concrete measurable quantitative hard goals. The refinement may be decomposition-driven or contribution/influence driven. Most approaches mention conflicting goals in relation with resource allocation.
Portfolio	Group of projects that may have together a common goal, that are executed in some period, that may share/compete for resources, and between which may exist dependencies.
IT artifact	Mostly refers to or software service or applications.

Table 1. Identified strategy and value-related concepts

III. ARCHIMATE

As mentioned before, we use the ArchiMate 2.0 language, and a set of proposed additional concepts, to capture the alignment between the fields of business strategy, business requirements management, enterprise architecture and portfolio management. In order to do that, we first briefly describe the ArchiMate core and its two existing extensions: the Motivation extension and the Implementation and Migration extension. Furthermore, we analyze to what extent ArchiMate is able to support the value-related concepts identified in Section II.

A. The ArchiMate core

Fig. 2 shows a simplified version of the ArchiMate core metamodel. The language distinguishes between three layers: the business layer, the application layer, and the technology layer. Within each layer, ArchiMate considers the structural, behavioral, and informational aspects. It also identifies relationships between and within the layers. For a full description of the language, we refer to [18].

To facilitate architecture-based (quantitative) analysis, ArchiMate model elements could be annotated with attributes, which quantify measures associated with the

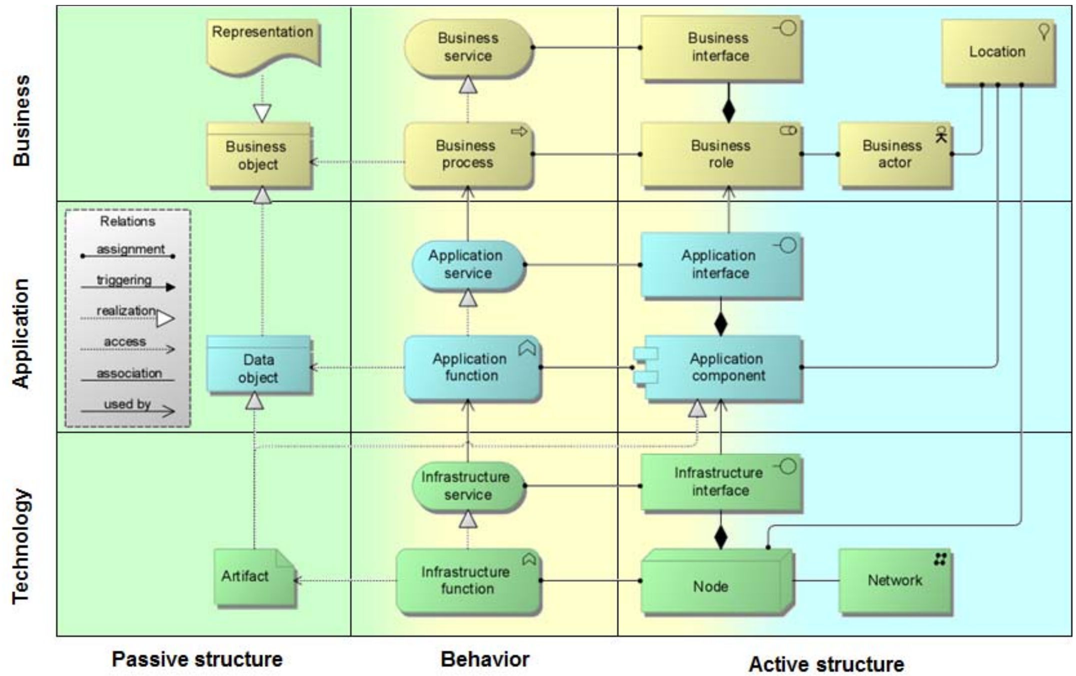

Fig. 2. Simplified ArchiMate metamodel

concepts and relationships. The nature of these measures may vary depending on the purpose of the concrete analysis technique used. For example, one may associate core elements with costs, performance measures, key performance indicators (KPIs), etc. Attributes can be defined for both input parameters and analysis results.

B. Motivation extension

A motivational element is defined as an element that provides the context or intention behind the architecture of a system or behind architecture decisions [10]. Intentions are pursued by people, called stakeholders. A stakeholder can be some individual human being or some group of human beings, such as a project team, enterprise or society. In addition, intentions may be organized into areas of interest, called drivers, such as customer satisfaction, compliance to legislation or profitability. Drivers represent internal or external factors that influence the plans and aims of an enterprise. Assessments of these drivers are needed to decide whether existing intentions need to be adjusted or not. The actual intentions are represented by goals, principles and requirements. Goals represent some intended result – or end – that a stakeholder wants to achieve.
Principles and requirements represent intended properties of solutions – or means – to realize the goals. Principles represent intended properties that are required from all possible solutions in a given context. For a more detailed description of this ArchiMate extension, we refer to [18]. Fig. 3 shows the metamodel of the motivation extension.

C. Implementation and migration extension

The implementation and migration extension proposes several additional concepts that enable the modeling of the architecture change process and in order to increase insight into these changes as well as their manageability in terms of portfolio and project management decisions. By defining concepts such as work package, deliverable, gap, and plateau it is possible to connect ArchiMate with program and project management standards and best practices, such as PRINCE2 [21] and PMBoK[24].

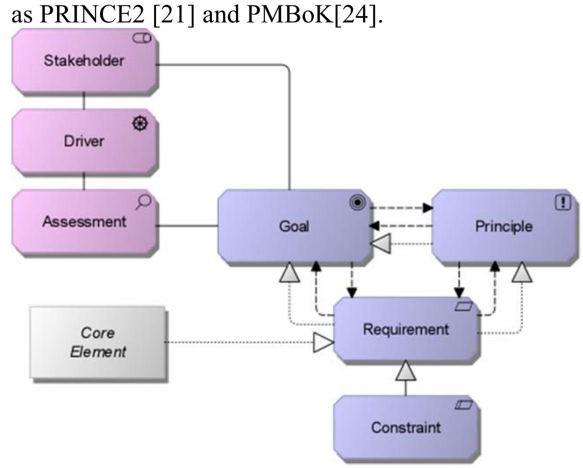

Fig. 3. Motivation extension metamodel

The central behavioral concept in the implementation and migration layer is a work package. A work package is basically a management environment that has a clearly defined beginning and end date, and aims to achieve/deliver a well-defined set of goals/deliverables. The work package concept can be used to model projects, but also, e.g., subprojects or tasks within a project, programs, or project portfolios. A work package is defined as a series of actions designed to accomplish a unique goal within a specified time. An important premise in any architecture development process is that the various architectures are described for different stages in time. Thus, transition architectures can be defined, showing the enterprise at incremental states reflecting periods of transition (i.e., "milestones") between the as-is and the to-be architectures. Transition architectures could also be used to allow for individual work packages and projects to be grouped into managed portfolios and programs, illustrating the business value at each stage. In order to support this, the plateau concept was defined in this language extension. Relationships can be established between EA models created at different moments in time and the migration models. Subsequently, analysis tools can be used to emphasize the differences between the different versions of models trough the linked plateaus. These differences are captured by the concept of gap. The metamodel of this extension is shown in Fig. 4.

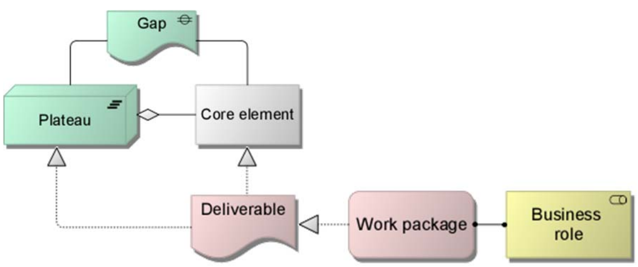

Fig. 4. Implementation and migration metamodel

D. Strategy and valuation concepts and ArchiMate

Several strategy and valuation concepts have been identified in Section II. In this section we will revisit each of the identified value-related concepts and establish to what extent they have a representation in ArchiMate core and its extensions.

- *Value*. The value concept is already defined in the ArchiMate core as the relative worth, utility, or importance of a business service or product. Value is often expressed in terms of money, but it has been long recognized that non-monetary value is also essential to business; for example, practical/functional value (including the right to use a service), and the value of information or knowledge. Although value may concern some internal system or organizational unit, it is most typically applied to external appreciation of products or services, normally as part of some sort of customer-provider relationship. Therefore, in ArchiMate, the value concept is confined to the business layer and, thus, may only model some business value. In this paper we argue that each architectural element carries one or more types of value, and subsequently contributes to the value of other architecture components. Thus, value must be present in all architecture layers and it propagates through the architecture until, eventually, it is translated in business value at the business layer.
- *Value exchange*. Our interpretation of this relationship's definition [12] is that of a flow of value between two actors. As such, it could be seen as a specialization of ArchiMate's flow relationship.
- *Cost*. Since cost is a property that, practically, can be associated with any architectural entity and/or IT project we propose to define cost as an attribute of any architecture element. This mechanism was already used in the architecture-based cost analysis technique proposed in [16].
- *Goal and goal refinements*. Both goals and goal refinement are well addressed in the motivation extension (see [18]). The aggregation and the realization relationships are particularly suitable for supporting goal refinement.
- *Project and Project Portfolio* can be modeled using the work package concept of the Implementation and Migration extension [18].
- *IT artifact*. The interpretation of this construct in most valuation techniques is that of software application. Despite this generic semantics associated with the construct, one may choose a specific ArchiMate concept (most probably belonging to the Application or Technology layers) to precisely specify such an IT artifact, and thus increase the accuracy of its specification. Examples of constructs that can be used to model IT artifacts are application components, data objects, application services, system software, etc.
- *Risk, Resource, Competence and Capability*. These concepts are currently neither supported by ArchiMate core nor by its extensions.
- *Constraint*. This concept has been only recently added to the language (in version 2.0) and does not cover operational constraints (e.g., control flow constraints). It should be noted that ArchiMate's constraint in its current definition is confined to the motivation extension. However, for valuation purposes, it should be possible to relate it to resources and risks, which is, essential in constrained optimization techniques in which projects may compete for the same resources.

IV. EXTENDING ARCHIMATE WITH STRATEGY AND VALUE-RELATED CONCEPTS

When extending ArchiMate with strategy and value-related concepts we followed a number of important principles listed below:

- **Reuse** of concepts and ideas from existing valuation techniques and models.
- **Alignment** with ArchiMate: the proposed language fragment should be aligned with the current ArchiMate metamodel specification.
- **Parsimony and ease of use**. The number of additional concepts is kept to a minimum. Whenever possible, existing ArchiMate concepts and relationships are re-used or specialized. The new concepts are easy to learn, understand and use.
- The new concepts easily accommodate **model-based valuation techniques**.

The indented semantics of the business strategy & portfolio management concepts is transferred to the new concepts through the proposed concept definitions that entirely rely on the reviewed business strategy & portfolio management literature. In addition, the new concepts have been related to existing ArchiMate concepts to ensure consistency with the current language concepts. One of our ongoing research is an ontological analysis of the new concepts, which will further strengthen/ensure their semantic interoperability with ArchiMate concepts. In the remainder of this section we define and explain the concepts, the relationships these concepts have with each other and with the concepts defined in ArchiMate 2.0, and the abstract and concrete syntax of the proposed language fragment.

The ArchiMate definition of value, although restrictive, fits in the general definition of value as assumed by valuation techniques. For this reason we propose an extension of the definition in order to cover a broader range of value types. Thus, ***value*** is defined as the relative worth, utility, or importance of a core architectural element (e.g., service, product, process, application component, etc.), or of a project.

An important limitation of ArchiMate and its extensions is that values can only be related to products and services. Therefore, we adapt the ArchiMate metamodel, as shown in Fig. 5, such that value can be *associated* with any core concept, the goal concept and the work package concept. Value is *assigned* by stakeholders. As mentioned before, a goal represents some end that a stakeholder wants to achieve. In principle, an end can represent anything a stakeholder may desire, such as a state of affairs, a realized effect or a created property. This definition indicates that a goal represents the intention to change (most likely increase or maximize) or maintain some value. In the literature a distinction is made between achievement goals and maintenance goals [15]. Although, one can have the goal of maintaining a certain state of affairs, such a goal is motivated by the fact that the above-mentioned state of affairs is beneficial in some way or it is decreasing/minimizing some risk. Thus, also maintenance goals eventually positively contribute to some sort of value. We model the relationship between goal and value by means of the *association* relationship. Also, we propose the usage of attributes for the specification of a value type, for its measures (mostly expressed in terms of quantifiable KPIs) and for its nominal or ordinal measurements.

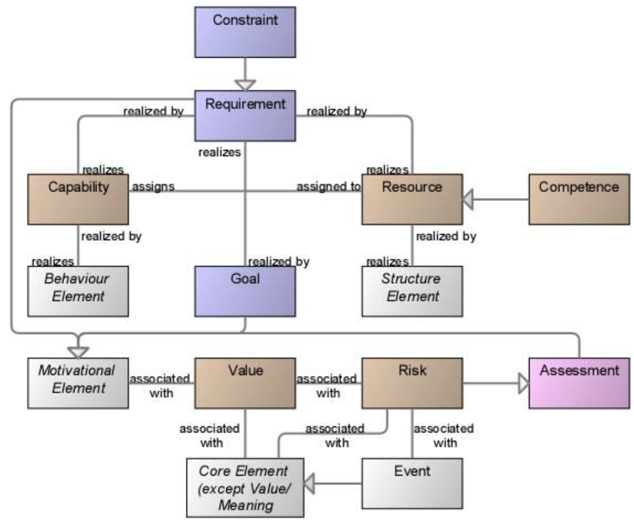

Fig. 5. Abstract syntax (metamodel fragment) for strategy and value-related concepts

For the concept of ***risk***, we adopted the definition of The Open Group (2009): “the frequency and magnitude of loss that arises from a threat (whether human, animal, or natural event).” The most common risk calculation formula is that of the threat’s probability multiplied with the magnitude of its effect (i.e., the size of the value loss). This definition clearly indicates that a risk should be *associated* with some *event* (the occurrence of which represents a threat) and with some *value* (loss). Although new, the risk concept is not introduced in the language as an independent concept, but as *specialization* of the assessment concept from the motivation extension, since it represents the outcome of some risk *assessment*.

The ***resource*** concept is prominently present in most valuation techniques, and especially in constraint optimization models in which they are mathematically defined and constrained. We defined a *resource* as an asset owned or controlled by an individual or organization. We relate the resource concept to the motivation extension, in particular to requirements and goals through the *realization* relation. This relationship is motivated by the fact that the achievement of a goal assumes the availability and (constrained) consumption of certain resources. This view is based on the mathematical formulation of constrained optimization models in which a goal function is minimized/maximized subject to a system of constraints (expressed as inequalities) imposed to the resources to be consumed for the achievement of the goal.

Thus a resource may realize a requirement, which in turn, may realize a goal. Furthermore, a resource is *realized* by structure elements, and as such we can regard it as an abstraction of structure elements.

Fig. 6 Concrete syntax (Notation)

From the competence definition presented in Table 1, adapted from [23], we infer that the ***competence*** concept is a *specialization* of resource (intangible or personnel-based). This is based on the fact that the definition of competence proposed in [23] is almost identical with that of personnel-based resources (see Table 1). However we agree that, depending on the (interpretation of the) definition of competence, one may argue that, for example it is more natural to introduce competence in the metamodel as a specialization of a capability (which is defined next). Nevertheless, we believe that competence should not be defined as independent concept as the semantic distance between competence, on one hand, and either resource or capability, on the other hand, is too small.

Capability is defined as the ability (of a static structure element, e.g., actor, application component, etc.) to employ resources to achieve some goal. This definition indicates that capability (similarly to resource) can be seen as an abstraction of some behavior of the static structure element. Also capability assumes the ability to employ (i.e., configure, integrate, etc.) resources. This relationship will be modeled through the *assignment* relationship.

Similarly to value, we use the existing ***constraint*** concept and extend its definition. Thus, constraint is defined as a restriction on the way capabilities and systems are realized and resources are employed. This means we relate it to the resource and capability concepts as well.

The language fragment metamodel presented in Fig. 5 summarizes the discussion carried out so far in this paper, which definitions and motivates the included concepts and relationships. It should be however noted that more relationships could be derived as a result of the application of ArchiMate's composition of relationships mechanism described in [6]. This metamodel is aligned with the core metamodel. Fig. 6. Depicts the graphical notation for the proposed language fragment.

V. THE APPLICATION PORTFOLIO CONSOLIDATION CASE

Consolidation of software application portfolios is a typical situation in which portfolio management techniques are applied. The main goals of the consolidation of IT resources are the elimination of functional and data redundancies. Typical situations in which IT consolidation is necessary include the co-existence of different software systems in an organization that offer the same functionality, or the replication and storage of data by several different systems.

The positive effect of IT consolidation on cost reduction has long been recognized in the literature (e.g., [14]). In particular, we refer to [11] that used integer binary programming to solve the IT consolidation problem, while minimizing consolidation and maintenance costs. We apply the technique proposed in [11], in a model-based fashion, to enterprise architecture enhanced with strategy and value-related concepts.

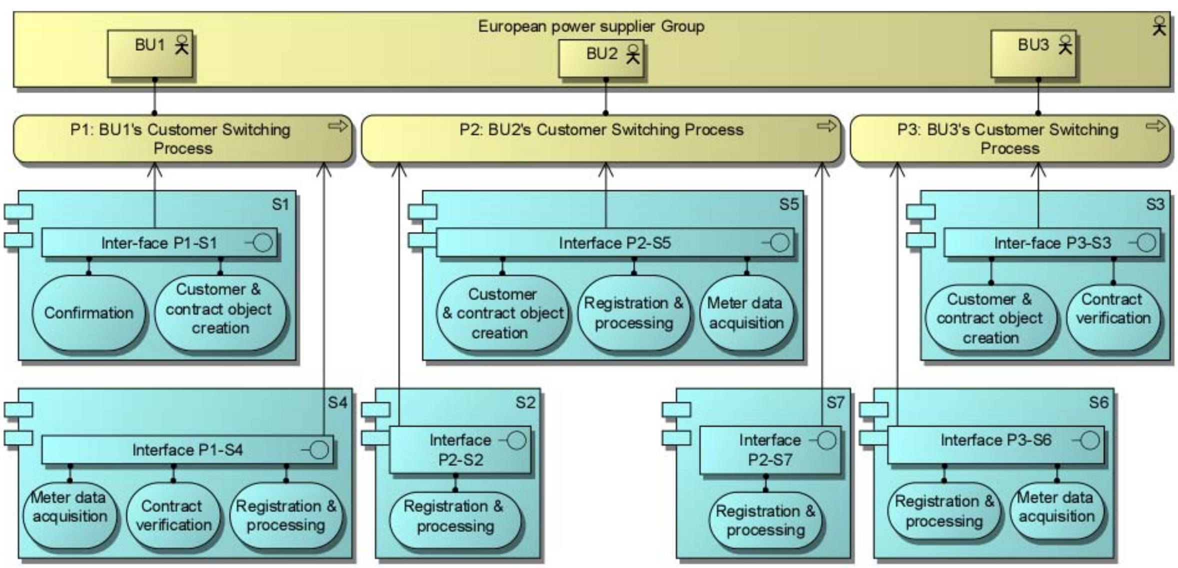

Fig. 7. EES baseline enterprise architecture

As an example, we consider the same case as in [11], namely, that of a large European energy supplier (EES). As a result of the energy market liberalization, this energy supplier must be able to ensure a fast and reliable switching process for new and leaving customers. Currently, the company has seven different application systems that all take care of switching for three business units, and provide overlapping functionality. We used the information provided in [11] to extract and specify the current state of the EES's enterprise architecture (Fig. 7). The overlapping functionality is modeled as identical application services offered by the seven systems (S1 – S7). Although similar, the three switching business processes (i.e., P1, P2, and P3) are not identical. Therefore, they pose slightly different functional requirements to the application systems supporting them, and thus they require the usage of different application services.

EES plans to consolidate its application portfolio and discard some of the seven systems, subject to the following constraints:

- All processes remain operational. This means that if a process is now using systems that are going to be removed, new connections (i.e., interfaces) have to be built to the remaining systems such that the process can make use of the exact same services as before the consolidation.
- A system cannot be removed if this leads to functionality loss.

Next to more control and elimination of system redundancy, the most important goal of the consolidation operation is to minimize systems maintenance costs and implementation costs for new connections between systems and the three processes.

To model the above application selection problem, and its

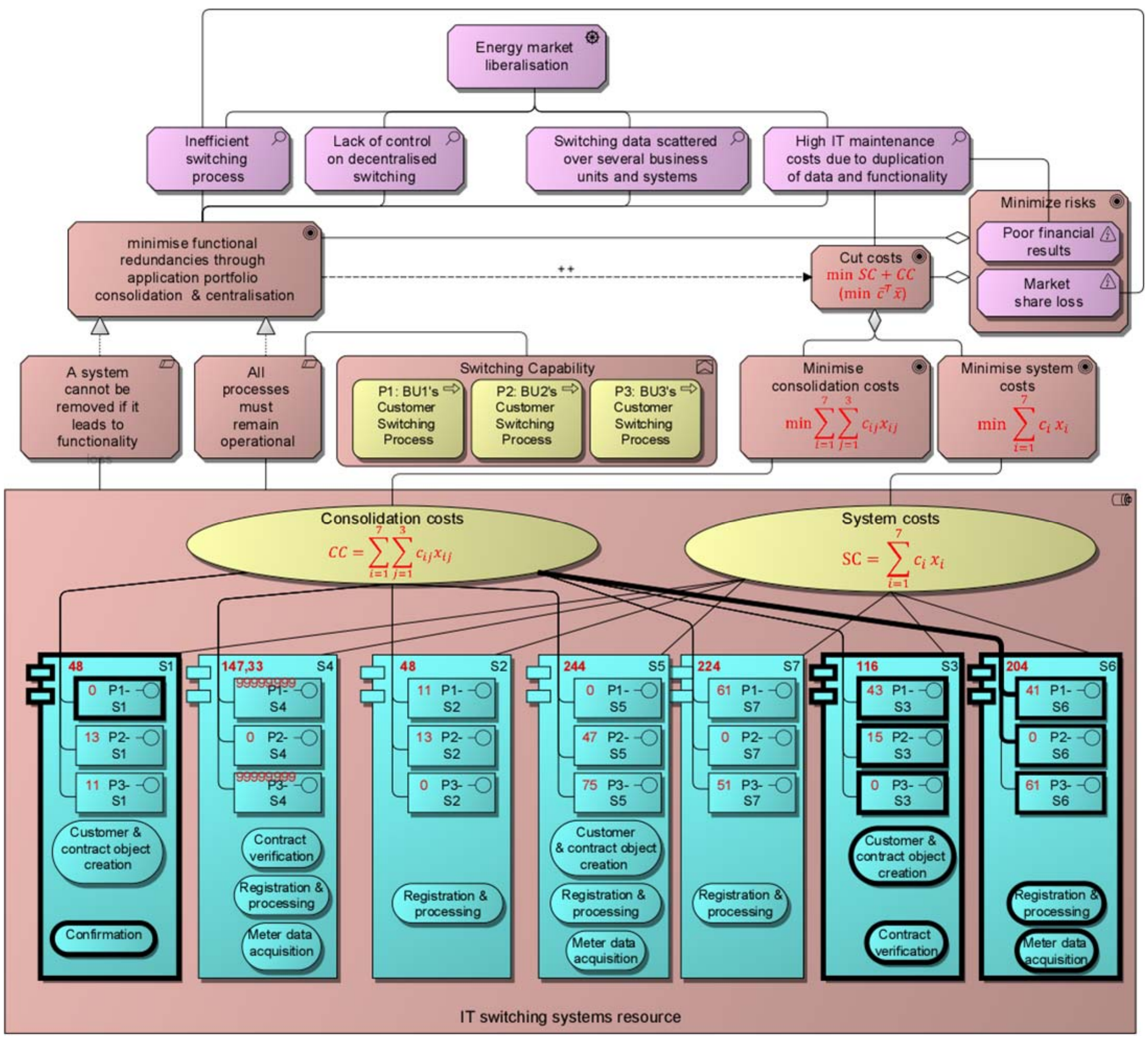

Fig. 8. Motivation, values, resources, capability, constraints and risks in the EES case

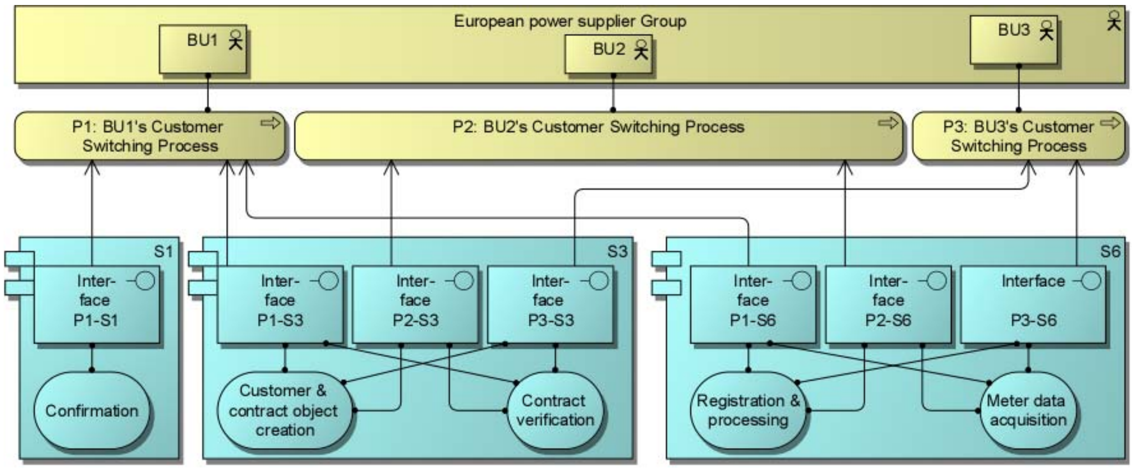

Fig. 9. The target EES architecture

motivations (i.e., goals) we have created the model depicted in Fig. 8.

Next to ArchiMate concepts, this model illustrates the usage of the newly added strategy and value-related concepts, such as, value, risk, constraints, resource and capability. Furthermore, the model contains the mathematical definitions of value measures and goals, and the costs associated with systems and all (possibly new) interfaces offered by systems to processes (specified as numbers (in red) in the top-left corner of some of the model elements). The quantitative input with which the architecture model has been enriched, has been taken over from [11] where realistic estimates of these costs are provided. On this model any existing algorithm for solving a binary integer programming (BIP) problem can be applied (by using an arbitrary BIP solver software). In Fig. 8 the optimal solution for EES's BIP selection problem is also shown, and consists of the systems, interfaces and services that have a thick border. This solution leads to an important reduction of the maintenance and implementation costs, as demonstrated in [11]. Furthermore, based on the optimal solution, the design of the consolidated target architecture can be determined (see Fig. 9).

Please note that, for the sake of models' clarity, no projects have been modeled. However, each of the systems can be seen as deliverable of a separate consolidation project, and thus the application selection problem can also be modeled as a project portfolio management problem.

VI. Conclusions

The main contribution of this paper is threefold. First, we have identified the modeling concepts that are needed for the alignment of three disciplines, i.e., business strategy, EA and portfolio management. Second we have investigated to what extent ArchiMate, as international EA modeling standard, supports the above mentioned modeling domains, and third we proposed several new concepts that enhance ArchiMate and fill the identified modeling gap. Our approach is illustrated with a case study that demonstrates the expressive power of the proposed language fragment. In addition, it also shows that enriching ArchiMate with these new concepts facilitates the application of quantitative portfolio management techniques (in this particular case a constrained optimization technique - BIP), and possibly of other quantitative analysis techniques, in an architecture model-based fashion. This brings existing theory and analysis techniques from strategic management and portfolio management to the domain of enterprise architecture modeling. Currently we plan to apply the proposed modeling approach in consultancy projects. These projects help us to further validate and improve it. Furthermore, our future work aims at the elaboration for EA of other analysis techniques, using existing work, such as the work referred to in this paper. Next to this, we plan to integrate these analysis techniques in the ArchiMate modeling tool we used to create all presented models. This tool already implements the ArchiMate 2.0 metamodel extended with the fragment proposed in this paper.

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http://www.novay.nl/okb/projecten/archivalue/7240.

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