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A Modeling Method in Support of Strategic Analysis in the Realm of Enterprise Modeling

On the Example of Blockchain-Based Initiatives for the Electricity Sector

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Abstract. *Organizations increasingly have to cope with the digital transformation, which is ubiquitous in today's society. Strategic analysis is an important first step towards the success of digital transformation initiatives, whereby all the elements (e. g., business processes and IT infrastructure) that are required to achieve the transformation can be aligned to the strategic goals and decisions. In this paper, we work towards a modeling method to perform model-based strategic analysis. We explicitly account for information technology (IT) infrastructure because of its key role for digital transformation. Specifically, (1) based on a conducted study on business scholar literature and existing work in conceptual modeling, a set of requirements is first identified; (2) then, we propose a modeling method that integrates, among others, goal modeling, strategic modeling, and IT infrastructure modeling. The method exploits, among others, three previously designed domain specific modeling languages in the Multi-Perspective Enterprise Modeling (MEMO) family: GoalML, SAML and ITML; (3) we illustrate the use of the modeling method in terms of a digital transformation initiative in the electricity sector; and finally, (4) we evaluate the proposed modeling method by comparing it with the conventional SWOT analysis and reflecting upon the fulfillment of the identified requirements.*

Keywords. Strategic analysis • Conceptual modeling • Model-based analysis • Blockchain

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1 Introduction

In the era of digital transformation, the introduction of new technologies is no longer limited to an operational change in an organization's IT landscape (Matt et al. 2015), but may imply a fundamental transformation of all enterprise aspects, including products, services, and business processes (Hanelt et al. 2015; Matt et al. 2015; Westerman et al. 2014). Such a fundamental transformation is exemplified by a digital transformation of the Finnish Tax administration. As explained by Parviainen et al. (2017), instead of merely replacing paper-based tax forms by their digital counterparts, the Finnish Tax authorities have made sure that employers and banks use IT to directly send the relevant tax information to the tax authorities. As a result, citizens only have to do a final check on the correctness of the tax data. This is an example whereby technology fundamentally changes the way work is done, from a situation wherein citizens have to manually fill

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out tax forms, to citizens only having to do a final check of the result.

To cope with such fundamental transformations, it is important to formulate a digital transformation strategy (Hess et al. 2016; Matt et al. 2015). Such a strategy, which concerns "[...] the transformation of products, processes, and organizational aspects owing to new technologies" (Matt et al. 2015), can be used to systematically address the various areas affected by digital transformation. In this paper, we focus on such a strategic formulation in the context of digital transformation, and investigate strategic analysis tools and approaches, which may be used to support assessment of, among others, planned (digital) initiatives.

A strategic formulation requires "the development of long-term plans, to effectively respond to environmental opportunities and threats in the light of the strengths and weaknesses of the company" (Houben et al. 1999). In this context, a SWOT analysis (Strength, Weakness, Opportunity and Threat Analysis) is an instrument that is traditionally used (Helms and Nixon 2010). However, although SWOT is a well-established and often used approach, it is also considered to be vague and oversimplified (Helms and Nixon 2010). As a response, approaches that extend SWOT have been proposed, which, among others, (1) suggest additional organizational aspects on which a SWOT analysis can be conducted (Fahy and Smithee 1999), such as organizational culture and technologies, or (2) propose to combine a SWOT analysis with other business scholar approaches, e. g., the resource-based view, cf. (Bell and Rochford 2016; Fahy and Smithee 1999; Panagiotou 2003; Valentin 2001).

Also, the conceptual modeling community have acknowledged the need for additional instruments supporting strategic analysis (Bock et al. 2016), and proposed different approaches (Bergmann and Strecker 2018b; Horkoff et al. 2014). However, as we discuss in Section 2, the existing modeling approaches either (1) do not provide semantically rich concepts, (2) are still in their development phase, or (3) fall short when it comes to allowing for integration with other perspectives on an organization and its environment.

Motivated, on the one hand, by this gap, and on the other hand, by the increasing number of digital transformation initiatives, in this paper we introduce a modeling method supporting strategic analysis that explicitly accounts for IT infrastructures. We follow the design school of strategy, cf. (Mintzberg et al. 1998), thus, in our interpretation of strategy we focus on the design process for establishing the fit between the internal capabilities and external possibilities and/or threats (Chandler 1962). To fulfill the goal of the proposed modeling method, which is to allow to rationalize the decision made, we treat IT as a white box taking into account the large range of both internal and external factors. To show the applicability of the proposed approach, we select an example from the smart grid domain, being one of the domains heavily affected by digital transformations (IEA 2017). Particularly, we focus on the blockchain-based NRGcoin initiative in the energy sector (Mihaylov et al. 2015).

In this paper, we continue our earlier work in the area of model-based strategic analysis, cf. (Kinderen et al. 2019), where we have proposed a Strategic Analysis Modeling Language (SAML), as part of Multi-Perspective Enterprise Modeling (MEMO) (Frank 2014) method. This contribution follows the design science research path (Hevner et al. 2004). The proposed method, created in an iterative manner, aims to support strategic decision making for digitalization initiatives, in terms of both (a) a *strategic fit analysis*, in the sense that our method supports problem structuring and strategic assessment of different alternatives for a given digitalization initiative; and (b) a *post-hoc rationalization* of made strategic decisions when evaluating digital initiatives.

As part of the paper, compared to our previous work, we deliver the following contributions: (1) Based on a conducted study of business scholar literature and existing work in conceptual modeling, we identify a set of requirements towards a modeling method to support strategic analysis. (2) We propose a modeling method that integrates goal modeling, strategic modeling, and IT infrastructure modeling. The method exploits three previously designed domain specific modeling languages in the Multi-Perspective Enterprise Modeling (MEMO) family: GoalML, SAML and ITML. (3) To illustrate the applicability of our method, we perform a detailed strategic analysis of the NRGcoin initiative in the electricity sector, in accordance to the steps of the proposed modeling method. Finally, (4) we evaluate the proposed modeling method by comparing it with the conventional SWOT analysis and reflecting upon the fulfillment of the identified requirements.

The rest of the paper is structured as follows. Sect. 2 provides a summary of strategic analysis with the main focus assigned to the SWOT analysis and its shortcomings. Having in mind the goal of this work, i. e., to propose a modeling method supporting strategic analysis that is informed by the internal and external multiple perspectives of an enterprise, in Sect. 3 we define a set of requirements for operationalizing such a method. Sect. 4 focuses on existing conceptual modeling approaches and their potential in supporting strategic analysis in terms of their fulfillment of the identified requirements. As our modeling method relies on the extension and integration of three domain-specific modeling languages, in Sect. 5 we present the abstract syntax of the resulting modeling languages bundle, and its implementation in a supporting modeling tool. Afterwards, we elaborate on our proposed modeling method in Sect. 6, and illustrate the application of our method to the NRGcoin case study in Sect. 7. Evaluation of our method is presented in Sect. 8. Finally, Sect. 9 concludes the paper, and presents an outlook for future research.

2 Strategic Analysis

A strategic perspective emphasizes the long-term outlook on an organization or a network of organizations. This long-term outlook informs analysis of an initiative to be undertaken, e. g., in terms of the long-term organizational goals being pursued and the influence these have on the value exchanges taking place, cf. (Gordijn et al. 2006), or the relation between value and the strategic orientation of an organization, cf. (Pijpers et al. 2012). Here, strategic orientation refers to analyzing, for a particular organization, the fit between its external situation and internal characteristics (Wegner et al. 2017). Such analyses are typically done with traditional business school instruments, prominent ones being the 5 Forces approach or Value Chain (Porter 1998), balanced scorecard (Kaplan and Norton 1996), and SWOT analysis (Helms and Nixon 2010).

For the remainder of this paper, we focus on SWOT. Partly due to its simplicity, SWOT is an often used approach to support the strategy formulation (Ghazinoory et al. 2011; Helms and Nixon 2010; Jarzabkowski and Kaplan 2015). Indeed, managers prefer this tool as “it is familiar and easy to use, requiring no training or specific competence to understand and apply” (Jarzabkowski and Kaplan 2015, p. 542), and because “it provides a good structuring device for sorting out ideas about the future and a company’s ability to exploit that future” (Piercy and Giles 1989, p. 5), cf. also (Glaister and Falshaw 1999).

SWOT “summarises the key issues from the business environment and the strategic capability of an organisation that are most likely to impact on strategy development” (Johnson et al. 2008, p. 602). Thus, SWOT allows one to compare internal qualities to the external situation, i. e., conduct already mentioned strategic fit analysis (Helms and Nixon 2010). Specifically, SWOT is used to assess qualities internal to an organization in terms of Strengths (S) and Weaknesses (W), and situations external to the organization in terms Opportunities (O) and Threats (T) (Hill and Westbrook 1997). A typical SWOT analysis lists favorable and unfavorable internal and external issues in the four quadrants of an analysis table, thus providing a better understanding of “how strengths can be leveraged to realize new opportunities and [...] how weaknesses can slow progress or magnify organizational threats”

(Helms and Nixon 2010, p. 1). The aim of the analysis of external opportunities and threats is to assess whether an enterprise can seize opportunities and, at the same time, avoid threats when facing an uncontrollable external environment, cf., (Chang and Huang 2006). In turn, the internal strengths and weaknesses are analysed with the aim to assess how an enterprise carries out its internal processes.

Although SWOT is a popular tool used to assess alternatives and complex decision situations (Helms and Nixon 2010; Jarzabkowski and Kaplan 2015), as already mentioned, it is considered to be *vague* and *oversimplified* (Helms and Nixon 2010). Indeed, despite its use being routinized in many organizations, cf. (Jarzabkowski and Kaplan 2015), SWOT has been assessed as having little intellectual content (Hill and Westbrook 1997), and exhibiting the following disadvantages:

(1) *Inadequate definition of factors*: when applying SWOT, many factors can be identified. For instance, Hill and Westbrook (1997) point to the creation of long lists with over 40 factors (situations) on average. In addition, the identified factors have rather general (often meaningless) descriptions using unclear and ambiguous words and phrases (Ghazinoory et al. 2011). As a result, the descriptions often lack specificity, cf. (Pickton and Wright 1998).

To support users in providing more adequate description of factors, business scholar literature either combines SWOT analyses with other approaches to enrich the planning process (Hussey 1997; Panagiotou and Wijnen 2005), or proposes extensions to the SWOT approach. Regarding the former, some have combined SWOT with such techniques as Porter's Five Forces Model or the Resource-Based View (RBV), with the aim to consider additional perspectives in the analysis process. For instance, Fahy and Smithee (1999) adopt the RBV of the firm to provide a further assessment of the strengths and weaknesses internal to an organization, as identified per SWOT, so as to identify strategic resources and make a comparison with competitors. For a given "strength" one can use the RBV to assess its rarity, substitutability, and how easily the strength can be replicated (or imitated) by others. Regarding the latter, i. e., extending the SWOT framework, extensions have been proposed which aim at providing more meaningful definitions of considered factors. For instance, Panagiotou (2003) and Panagiotou and Wijnen (2005) propose an extension called a telescopic observations strategic framework, which maps strengths, weaknesses, opportunities, and threats against suggested categories such as technological advancements, economic considerations, legal, and regulatory requirements.

(2) *Lack of prioritization of factors* (Coman and Ronen 2009; Phadermrod et al. 2019): if SWOT analyses are to assist decision-makers in strategic planning, it is pertinent that the factors are noted in terms of their critical and/or causal importance. Indeed, "[m]ost SWOT analyses focus on an excessive number of the organization's strengths and weaknesses rather than on the main ones, which makes it difficult to translate the findings into actions" (Coman and Ronen 2009, p. 5677). It follows that SWOT analysis is not able to quantify the effects of weight and strategic factors on considered initiatives.

To rank and prioritize SWOT items, SWOT has been extended with quantitative methods, such as the Analytic Hierarchy Process (AHP)-SWOT (Kurttila et al. 2000), Analytic Network Process (ANP)-SWOT (Yueksel and Dagdeviren 2007), Quantified SWOT (Chang and Huang 2006), and Importance-Performance Analysis (Phadermrod et al. 2019).

(3) *Lack of analysis of relationships between factors* (Coman and Ronen 2009; Sammut-Bonnici and Galea 2015): in case of SWOT there "is no indication of causality among the strengths and weaknesses, nor are they ranked into any hierarchy" (Coman and Ronen 2009, p. 5677). Therefore, various authors suggest that an analytical approach should "go beyond the mere generation of lists under each heading and should seek to determine the cause and effect arising from each factor in the process" (Sammut-Bonnici and Galea 2015, p. 8).

(4) *Over-subjectivity in the generation of factors*: Phadermrod et al. (2019) and Pickton and Wright (1998) point to a serious shortcoming of SWOT, namely relying on a subjective perception of SWOT workshop participants. Thus, the conducted analysis suffers from a so-called compiler bias, and usually there is no attempt to verify any points undertaken (Hill and Westbrook 1997). Indeed, workshop participants often fail to include views and suggestions based on different data and analyses, factors are missed out and not treated in a comprehensive manner (Hill and Westbrook 1997; Phadermrod et al. 2019; Pickton and Wright 1998).

(5) *Ambiguous classification*: different authors point out that classification of factors in one of four SWOT quadrants is challenging as the same factor may fit in two categories (e. g., a strength and a weakness at the same time) (Pickton and Wright 1998). In addition, their classification may change in time, e. g., not maintained strengths may become weaknesses, and opportunities not capitalized upon, when adopted by competitors, may become threats, cf., (Ghazinoory et al. 2007, pp. 99-100).

(6) *Vague methodological support*: as Coman and Ronen (2009, p. 5677) argue, "[n]o straightforward methodology has been proposed to identify strengths and weaknesses." On the contrary, "typical procedural guidelines consist largely of catchall questions devoid of explicit theoretical underpinnings. Too often, they produce shallow misleading results" (Valentin 2001, p. 54).

In order to address this shortcoming, dedicated methods emerged (Chang and Huang 2006; Coman and Ronen 2009; Phadermrod et al. 2019; Valentin 2001). For instance, Coman and Ronen (2009, p. 5681) propose to use the Event-Factor-Review methodology to derive strengths and weaknesses from business events.

(7) *Lack of context*: various scholars point out that SWOT analysis does not provide a sufficient context for adequate strategy optimisation (Chermack and Kasshanna 2007; Clardy 2013; Kotler 2000; Panagiotou and Wijnen 2005). The context encompasses among others, strategy and goals of a company, its activities, and other aspects of enterprise action system. In line with these criticisms, Bock et al. (2016) state that a relation of the strategic approaches to a detailed understanding of other aspects of an organization is often missing, with the latter, e. g., IT infrastructure, being treated as a black box (Bock et al. 2016, p. 48).

3 Modeling Support for Strategic Analysis of IT – Requirements

As discussed, we aim at addressing the flaws of traditional strategic analysis and provide analysts with a supporting instrument that would help them explore scenarios and find alternative strategies. In line with the approach to design modeling methods we follow in this paper, cf. (Frank 2010), based on a study of business scholar literature, existing work in conceptual modeling, and scenario analysis, we identify a set of requirements for our modeling method. Following Frank (2011), we understand a modeling method as (1) an approach "aimed at solving a class of problems through the design and use of models" (Frank 2011, p. 40), and (2) consisting of "at least one modeling language and at least one corresponding process model which guides the construction and analysis of models" (Frank 2011, p. 40). Therefore, the identified requirements relate to both, supporting modeling languages (e. g., concepts that should be delivered by a modeling language), as well as a supporting process model (e. g., aspects that should be modeled during the analysis process).

In what follows, we present a list of requirements derived from the conducted study on business scholar literature and existing work in the field of conceptual modeling (cf. Sect. 2):

Requirement 1: Modeling strategic factors and expressing their qualities for the needs of strategic fit analyses.

Rationale: As already discussed in Sect. 2, strategic orientation refers to analyzing, for a particular organization, the fit between its external situation and internal characteristics (Wegner et al. 2017). As in traditional SWOT analysis expression of factors/situations is usually very brief and general in nature, cf. (Hill and Westbrook 1997), therefore, the targeted modeling method should allow for modeling of situations and their qualities forcing analysts and decision makers to be more specific.

Requirement 2: Provision of well-specified, semantically rich concepts.

Rationale: to address vagueness and oversimplification, two aspects which SWOT is mostly criticized for (cf. Sect. 2), a modeling method which supports a strategic analysis should provide differentiated analysis capabilities. This implies that our modeling method should cater for a rich set of domain-specific concepts with a rich set of attributes and constraints that one could use during the analysis process. In particular, based upon the literature we recommend accounting for the following:

- **Requirement 2a:** Accounting for concepts from approaches complementary to SWOT.
  Rationale: as discussed in Sect. 2, complements and extensions (e. g., telescopic observations strategic framework (Panagiotou 2003)) to SWOT have been proposed to enable a more differentiated analysis. Please note that complementing SWOT with well-established approaches such as, e. g., the resource-based view on the firm (as discussed in Section 2), allows to provide a more complete picture, cf. (Bell and Rochford 2016; Marti 2004; Valentin 2001). Indeed, the resource-based viewpoints that in times of rapid change, competitive advantages are mainly due to company (tangible and intangible) resources and capabilities (i. e., core competences, core knowledge). But the resource-based view, in isolation, does not completely explain how to deploy scarce resources to create superior value because it focuses only on what the organization has, cf. (Marti 2004). Therefore, other complementary perspectives, e. g., the activity-based view focusing on what the organization actually does, is necessary (cf. Requirement 6).
- **Requirement 2b:** Enabling differentiation among elements belonging to strategic analysis by considering their importance, e. g., through accounting for weights or probabilities of occurrence.
  Rationale: Lacking prioritization of considered factors is one of the major shortcomings of SWOT. Phadermrod et al. (2019) and Shinno et al. (2006) propose to assign weights to SWOT elements, respectively, by means of relative importance in terms of a pairwise comparison of the SWOT elements (Shinno et al. 2006), and absolute weights of SWOT elements, measured through a combination of an element's importance and performance as perceived by customers (Phadermrod et al. 2019). In addition, for the needs of reasoning, it should be possible to state what is the occurrence level of a situation, i. e., "the degree to which a situation occurs in the current state-of-affairs" (Horkoff et al. 2014)
- **Requirement 2c:** Providing support for explanation and documentation.
  Rationale: The traditional SWOT approach is often criticized for relying on subjective perceptions of participants of SWOT workshops (Phadermrod et al. 2019). In addition, as users of strategic analysis may be different than its creators, it is important that each assessment is properly explained and documented/justified (e. g., what is understood as being part of some situation, or why we consider something as a strength), cf. (Helms and Nixon 2010; Phadermrod et al. 2019; Taghavifard et al. 2018).
- **Requirement 2d:** Using performance measures to characterize strategic factors.
  Rationale: For the purpose of monitoring and control, it is recommended to quantify selected aspects of business activities, cf. (Coman and Ronen 2009; Horkoff et al. 2014), i. e., to account for performance measures. Performance measures are quite often captured by using indicators/metrics, cf. (Strecker et al. 2012).

Requirement 3: Accounting for a rich set of relationships.

Rationale: a SWOT analysis leads to the creation of a table of SWOT items, cf. (Helms and

Nixon 2010). As such, it does not account for the complexity of the phenomena and resulting consequences, thus, not allowing to conduct a more sophisticated analysis. Also, as already mentioned in the previous section, Sammut-Bonnici and Galea (2015, p. 8) stress that SWOT "should go beyond the mere generation of lists under each heading and should seek to determine the cause and effect arising from each factor in the process."

Therefore, the said set of relationships should allow to account for causality relations among all SWOT concepts (e. g., cause, effect) as well as to account for hierarchies of different states, cf. Sect. 2. In addition, a differentiated set of relationships is necessary simply to account for Requirement 6 defined below to relate elements of a SWOT analysis to IT infrastructure elements, and potentially other elements of the enterprise action system.

Requirement 4: Accounting for context-specific classifications.

Rationale: When it comes to the classification of a given situation, the modeling approach should enable the classification of some situation in some context differently to account for the fact that "external (or internal) factors of an organization are not always opportunity (strength) or threat (weakness); in other words, in different conditions, they have different meanings" (Taghavifard et al. 2018). Therefore, contingent classification of situations should be accounted for, cf. (Hill and Westbrook 1997; Valentin 2001).

Requirement 5: Analysis of strategic factors needs to be complemented with a clear statement of goals of involved stakeholders as a frame of reference.

Rationale: A misconception is that SWOT can be done without reference to the organization's strategy and goals of involved stakeholders, cf. (Chermack and Kasshanna 2007; Clardy 2013). In fact, different goals and values of involved actors may emphasize certain factors, which in turn, may influence what a strength or a weakness might be, cf., (Kotler 2000).

Requirement 6: Modeling perspectives of the enterpise action system and, in particular, the information technology (IT) system, and relating them to strategic analysis.

Rationale: According to Chermack et al. (Chermack and Kasshanna 2007) and Bock et al. (Bock et al. 2016), an important shortcoming of typical SWOT analysis is that it lacks a systematic relation with the other perspectives on an organization. Indeed, in order to make an informed decision and decide on the strategy to follow, considering (other than goals) aspects of an enterprise action system (i. e., business processes, resources etc.) and IT, is important (Bock et al. 2016; Chermack and Kasshanna 2007; Mintzberg et al. 1998).

In the context of digital transformation, especially accounting for the IT perspective becomes crucial (Hanelt et al. 2015). Indeed, if a modeling language explicitly targets expressing the IT perspective, one can conduct a strategic analysis that is grounded in the actual IT capabilities of an organization.

4 Existing modeling approaches and fulfillment of requirements

Conceptual modeling plays an important role in supporting strategic analysis. In this section we present an overview of existing conceptual modeling techniques that support strategic analysis, and discuss the extent to which these modeling techniques fulfill the elicited requirements.

4.1 Conceptual Modeling Approaches

Existing conceptual modeling approaches that support strategic analysis can be roughly classified into the following categories:

1. Goal-oriented requirements engineering (GORE) approaches, which focus on goal modeling in general. These approaches can be used for strategy modeling, but contain only few elements that target strategy modeling specifically;
2. Strategy modeling approaches, which explicitly incorporate concepts from business scholar literature on strategic analysis; and

3. Enterprise modeling approaches, which focus on dedicated ICT infrastructure analysis capabilities to inform the strategic analysis.

Goal-oriented Requirements Analysis (GORE). There exist a variety of GORE modeling techniques, such as i-star (Yu 1997), the Goal-oriented Requirements Language (GRL) (Amyot et al. 2010), GoalML (Overbeek et al. 2015), and TROPOS (Bresciani et al. 2004). For a recent overview, we refer to (Horkoff et al. 2019). With their focus on modeling (short/medium/long)-term goals, these techniques form a useful point of departure for strategic analysis and have also been used to that extent, cf. (Gordijn et al. 2006). However, the focus on goals means that these general GORE techniques – with a few exceptions – are equally applicable to other types of analyses (such as agent interaction, privacy, or otherwise). Thus, in their key concepts they often do not fully address ideas pertaining to strategic analysis as we find them in the discussed business scholar literature.

Strategy Modeling. In line with the idea of analyzing the strategic fit, i-star explicitly recommends to make both an analysis of the goals internal to actors, as well as of the interactions between actors (Yu 1997). Likewise, in Roelens et al. (2019) the authors provide an approach to analyze strategic fit by combining a domain-specific modeling language (which includes concepts such as goals, value proposition, activity, process, and competence) with AHP and heat mapping techniques. The Business Intelligence Model (BIM) (Horkoff et al. 2014) offers concepts (e. g., goals, situations, influences, and indicators) to support strategic business analysis in terms of, both, (1) continuous monitoring of organizational goal fulfillment based on KPIs, and (2) analyzing the strategic fit, particularly in terms of a model-based SWOT analysis (Horkoff et al. 2014). The defined relations allow to reason on relationships between situations, influences, and indicators. Although the BIM approach seems to be a powerful tool, to the best of our knowledge, it is not integrated with other elements of an enterprise action system and information system. As a result, BIM does not allow for analyses that are based on concerns that cut across different perspectives (cf. R6).

Finally, there are initiatives for modeling strategic plans or strategic control. For one Bergmann and Strecker (2018a,b) aim at a differentiated conception of strategic plans. To this end, they develop an elaborate set of requirements and a first conception of strategic plans in terms of, e. g., different types of strategic plans and factors of influence. However, despite of being promising, those initiatives are still in the development phase, e. g., a process model to create strategic plans using the language has not yet been defined (Bergmann and Strecker 2018b, p. 19). Also, IT is not considered as as a first-class citizen in the conception of strategic plans.

Enterprise Modeling (EM). In terms of EM approaches, Archimate (Lankhorst 2017) allows for relating IT infrastructure and strategy, in the sense that: (1) its motivation extension (Lankhorst 2017, p. 80) allows for expressing strategy concepts, and its general motivational concepts (e. g.,'Goal") are explicitly mapped to concepts from the business scholar discourse on strategy (e. g.,"mission"), cf. (Aldea et al. 2015); (2) ArchiMate provides a rudimentary expression of IT infrastructure elements; and (3) ArchiMate provides the ability to express various relationships between layers (Lankhorst 2017, p. 107). However, being a language to express enterprise architecture concepts in general, ArchiMate's focus is not a strategic analysis of IT infrastructure per se. Therefore, various extensions have been proposed, e. g., (Azevedo et al. 2015; Quartel et al. 2012). And so, ArchiMate has been extended to relate business goals to IT projects and their underlying infrastructure (Quartel et al. 2012). Quartel et al. aim to value IT portfolios using ArchiMate together with Bedell's method to measure the strategic importance of IT infrastructure to organizations' goals. Nonetheless, the overall method only focuses on analyzing IT portfolios of a single organization. Moreover, while concepts from both IT infrastructure and strategy play a notable role here, the focus is actually placed on quantitative valuations. As such, the particular characteristics of IT infrastructure, and the implication this has for the organizational strategy, are less of a focus.

Similar to ArchiMate, ARIS (SoftwareAG 2017) offers concepts to analyze an organization from both a strategic and an IT infrastructure perspective, and provides the possibility to relate these perspectives. However, although ARIS offers more expressiveness than ArchiMate, as especially visible on the strategic end where ARIS combines concepts with a balanced scorecard analysis (SoftwareAG 2017, p. 187), the specific relation between IT and strategic analysis remains under-explored.

Considering a Multi-perspective Enterprise Modeling (MEMO) (Frank 2014), it offers a set of integrated Domain Specific Modeling Languages (DSMLs), such as languages for modeling business processes and organizational structures (OrgML, Frank 2014), goal modeling (GoalML, Overbeek et al. 2015), and, also relevant for our purposes, the Information Technology Modeling Language (ITML) for IT infrastructure modeling (Heise 2013; Kinderen and Kaczmarek-Heß 2018). As those DSMLs are integrated, IT infrastructure models can be related to organizational concerns, among others, goals of an organization, which fosters communication between stakeholders with different professional backgrounds, and allows for cross-perspective analyses (Heise 2013). In our previous work, we have proposed a Strategic Analysis Modeling Language (SAML). It provides a set of semantically rich concepts supporting multi-perspective strategic analyses, cf. (Kaczmarek-Heß et al. 2018), which we extend further in this paper.

Finally, e3-alignment (Pijpers et al. 2012) is proposed as a method for model-driven business-ICT alignment, relating organizations' strategic perspectives (described in e^3forces) to their corresponding IT/IS perspectives. However, the model-driven strategic analysis pertains mostly to the external market level only, whereas we require a focus also on the strategic analysis of *internal* (IT) resources. Also, the IT infrastructure is mostly depicted in an informal (arrow-and-boxes like) manner, which inhibits its differentiated analysis.

4.2 Fulfillment of requirements

Tab. 1 summarizes how the modeling approaches discussed in the previous section fulfill the elicited requirements. To estimate their fulfillment, we confront the requirements to the documentation of the discussed modeling approaches, in the form of peer-reviewed papers, technical reports, e. g., Barone et al. (2010) for BIM, or white papers, e. g., SoftwareAG (2017) for ARIS.

First, we consider GRL as an exemplary GORE modeling approach. In Tab. 1 one can observe that GRL partly fulfills a subset of the requirements of our modeling approach, including the ability to weight model elements both qualitatively and quantitatively, with according (semi-)automated reasoning support (addressing Requirement 2b), and the justification of model elements (addressing Requirement 2c). Yet being a general GORE approach GRL focuses less on strategic concerns specifically, as can be observed from the unfulfilled requirements pertaining to strategic (fit) analysis (e. g., concerning extensions to SWOT as per the strategic analysis literature, cf. Requirement 2a). In this sense, GRL is exemplary for the expressiveness of other general GORE approaches, which contain little in the way of strategic concerns. Considering another GORE approach i-star, it differentiates between an analysis of the goals of single actors, and the dependencies that exist between actors. In its focus on GORE i-star foregoes the internal-external dichotomy specific to strategic fit analysis.

Differently approaches falling under the umbrella of strategic modeling contain concepts that are of use for strategic modeling specifically. Here we highlight again BIM. BIM, as already discussed, offers various concepts in support of SWOT analyses, including a differentiated set of relations that reflect strategic concerns (cf. Requirement 3), as well as the intensity/importance of such relations (cf. Requirement 2b). Yet, while BIM certainly provides useful input for our modeling approach, as can be observed in Tab. 1, it

Table 1: Requirements fulfillment by discussed modeling approaches

Approach	**RQ1**	**RQ2a**	**RQ2b**	**RQ2c**	**RQ2d**	**RQ3**	**RQ4**	**RQ5**	**RQ6**
ArchiMate (Lankhorst 2017)	○	○	○	○	○	●	◑	◑	◑
ARIS (SoftwareAG 2017)	○	○	○	○	○	○	○	◑	◑
BIM (Horkoff et al. 2014)	◑	◑	◑	◑	●	◑	●	●	○
e3-alignment (Pijpers et al. 2012)	○	○	○	○	○	○	◑	○	◑
GRL (Amyot et al. 2010)	○	○	◑	◑	◑	◑	○	○	○
i-star (Yu 1997)	○	○	◑	◑	◑	◑	◑	◑	○
MEMO (Frank 2014)	○	○	◑	◑	◑	◑	●	◑	◑
MEMO-Strategy planning (Bergmann and Strecker 2018a,b)	○	◑	◑	◑	◑	◑	●	◑	◑

Legend: ○– not covered; ◑– partly covered; ●– largely covered

Summary of requirements:

RQ1: Strategic factors & qualities	**RQ2a:** Complementary concepts	**RQ2b:** Differentiation of concepts
RQ2c: Explanation & documentation	**RQ2d:** Performance measure	**RQ3:** Relationships
RQ4: Context-specific classification	**RQ5:** Stakeholders' goals	**RQ6:** IT perspective

falls short regarding several requirements, such as accounting for SWOT extensions (cf. Requirement 2a). Most prominently: being a standalone strategy modeling approach, BIM does not cater for a relation with other elements of an enterprise action system (cf. Requirement 6).

Finally, the selected enterprise modeling approaches – ArchiMate, ARIS, e3-alignment, and MEMO – all offer the possibility to express IT infrastructures. Also, being enterprise modeling approaches in line with Requirement 6, they can relate IT infrastructure to strategic analysis. However, they do so to a differing extent. Prominently, there is a contrast here between ArchiMate and MEMO, e3-alignment, and ARIS. ArchiMate and MEMO offer a rich set of relations to draw out relations between the IT infrastructure and strategic concerns. On the contrary, e3-alignment relies on informal, plain-text, guidelines only to relate the different perspectives to each other. For example, following Pijpers et al. (2012) such a guideline can be that if an actor occurs in an e3-forces diagram (for expressing strategic concerns), it should also occur in the IS architecture diagram (for expressing IT infrastructure). And when it comes to ARIS, as already discussed in the previous section, it lacks a differentiated relation between its IT modeling and strategy modeling capabilities.

In addition, the enterprise modeling approaches differ regarding their interpretation of "strategy". Here, ArchiMate emphasizes strategic concepts of importance to enterprise architects, such as a *Principle*, while in its strategic concepts e3-alignment takes its cues from Porter's five forces model (see Pijpers et al. (2012) for details). The strategic analysis of ARIS, meanwhile, is inspired by a balanced scorecard analysis SoftwareAG (2017, p. 180). When it comes to MEMO, on-going initiatives may be observed to enhance it to support the strategic decision process, cf., (Bergmann and Strecker 2018a,b; Bock et al. 2016). Bock et al. (2016) analyze various strategy analysis tools and critically reconstruct their concepts with the aim to demonstrate how those relate to and can be integrated with MEMO. However, a modeling method for strategic planning (Bergmann and Strecker 2018a,b), as already pointed out in the previous section, is still a research in progress. Nevertheless, looking at the requirements identified (Bergmann and Strecker 2018a,b), e. g., a need to express factors external to an organization and according semantically rich concepts, such as the concept *FactorOfInfluence* (Bergmann and

Strecker 2018b, p. 18), this initiative nicely complements our efforts. Yet importantly, in their interpretation of strategy none of the enterprise modeling approaches explicitly target the SWOT related concepts that we are after (especially regarding Requirement 2 and its sub requirements).

Furthermore, the expressiveness of the enterprise modeling approaches differs, which further influences the assessment on the respective requirements. For one, in its focus on enterprise architecture modeling, the concepts from ArchiMate contain little in the way of semantic expressiveness in terms of attributes, nor constraints. Similarly, e3-alignment offers only a rudimentary, high-level diagram of the IT infrastructure under assessment (the so-called IS architecture diagrams in Pijpers et al. (2012)). Differently, as part of its language family MEMO offers a dedicated modeling, semantically rich, language for IT infrastructure modeling. In a similar vein, the modeling method for strategic planning (Bergmann and Strecker 2018a,b), offers concepts dedicated to strategic planning.

4.3 Summary

As the above discussion clearly shows none of the existing approaches/methods fulfills all identified requirements. Therefore, to provide the desired modeling support for the needs of strategic analysis, we select the most comprehensive approach that fulfills our requirements to the largest extent and extend it with missing aspects. Regarding the selection, as the discussion points out, MEMO seems to be the most promising candidate for extensions: it already provides a semantically rich description of goals, processes and IT infrastructure. In addition, the MEMO language architecture allows for expressing the semantic richness of modeled concepts, as per Requirement 2.

The existing set of MEMO DSMLs needs to be extended regarding the coverage of strategic analysis. Also, explicit links with other perspectives need to be provided, prominently IT infrastructure. As we are interested in using different perspectives in tandem, they need to be integrated. This means that first the corresponding mappings between the different DSMLs need to be defined on the conceptual level. Only thereafter, the languages and mappings between them should be designed using the same language architecture, and implemented in a corresponding modeling tool.

5 Language design

As stated in the previous section, we continue our previous work with MEMO, and use the MEMO Meta Modeling Language (Frank 2010) (MML) to make necessary extensions, as discussed subsequently.

5.1 MEMO MML and Modeling Decisions

Several means of defining a modeling language exist. However, the one frequently used, also in case of MEMO, is by specifying a meta model, i. e., a model of models. As we extend already existing DSMLs, we use the MEMO method's common MML (Frank 2011), and thus, integrate the changes/extensions made into the MEMO method's language architecture (Frank 2014, pp. 947-950).

When compared to "traditional" meta modeling languages, MML provides additional language constructs for expressing: (a) intrinsic attributes and relations, and (b) language level types. Intrinsic attributes and relations are instantiated only on the instance level but not on the type level. They are visualized with a white letter "i" on a black background. In turn, language level types are instantiated on the type levels only, but not further on instance level. They are visualized with a grey background of the concept's name (Frank 2011, pp. 23-24).

In terms of the employed language design method, cf. (Frank 2010), it is notable that: (1) we consider the purposes and use scenarios as the first-class citizens that drive the design of the language landscape; and (2) we employ the guidelines for concept inclusion from Frank (2010). For example, the concept "involvementContext" (see Fig. 1) and its various attributes and relations conform to both the guideline "relevance", in terms

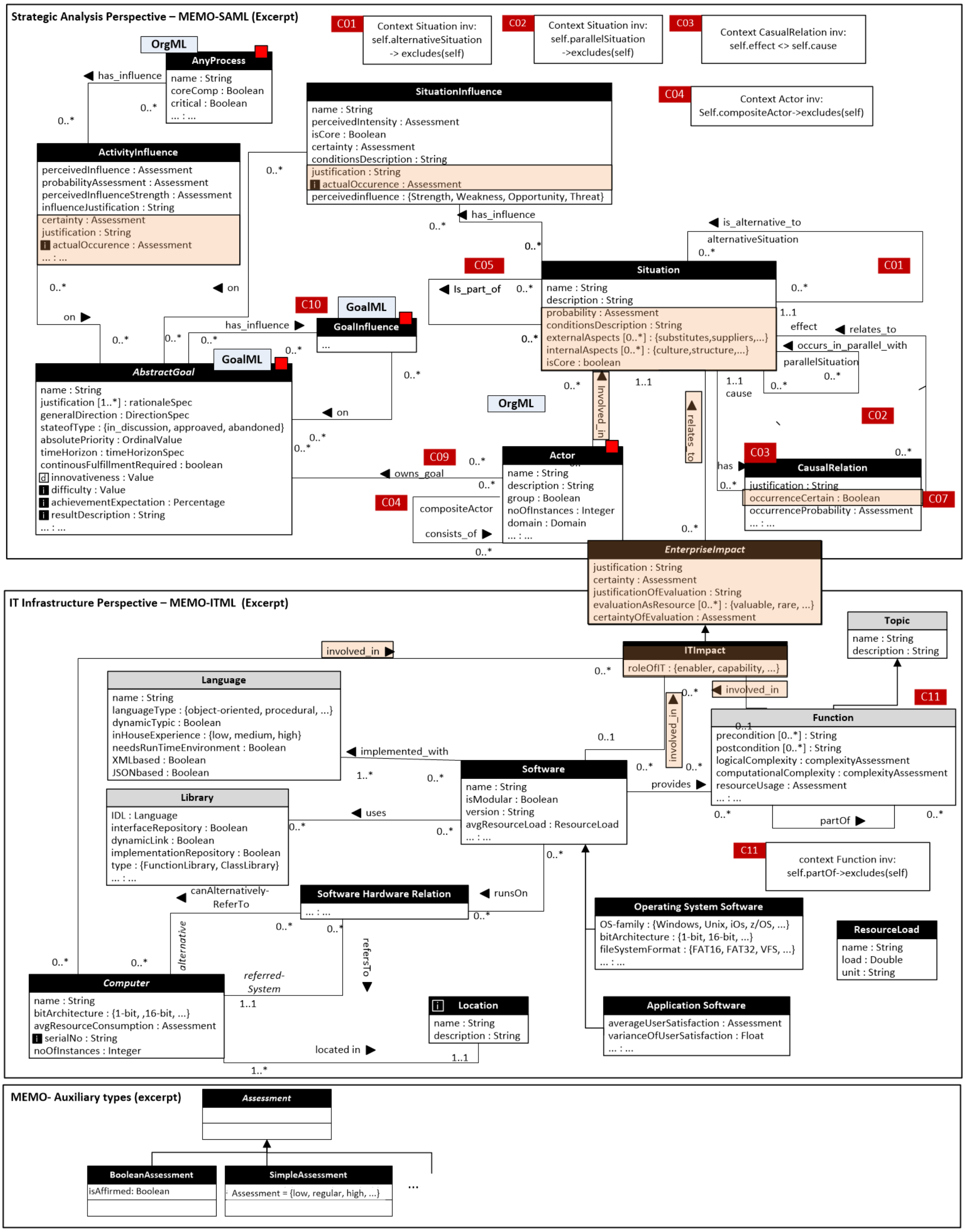


Figure 1: SAML and its associations to the extended ITML

of relevance to various analysis scenarios, and "invariant semantics", in the sense of its semantics being invariant over different analysis scenarios, as well as the concept having its own essential characteristics.

5.2 Abstract Syntax

Fig. 1 (the upper part) shows the key concepts of the proposed and continuously further extended Strategic Analysis Modeling Language (SAML) (cf. Kaczmarek-Heß et al. 2018; Kinderen et al. 2019), and its connections to concepts from other MEMO languages such as extended ITML (Kinderen and Kaczmarek-Heß 2018), GoalML (goal modeling), and OrgML (organization structure modeling) (Frank 2014).

The main concept for analysis is a `Situation`. In line with Barone et al. (2010, p. 9) and Horkoff et al. (2014, pp. 1017-1018), we define a situation as a partial state of affairs, captured by a structure that exists in that state and consists of relations and elements. Situations influence goals either positively or negatively depending on the relationship between them.

In opposition to other approaches (including also BIM), for us a `Situation` has a rich set of attributes allowing to describe the meant state, its probability, and its classification. Following Mintzberg et al. (1998), we differentiate among external technological, economics, social, and political aspects of an enterprise's environment, which are assumed to be not under the enterprise's control. In turn, internal elements are organization's culture, structure, and resources, which are assumed to be under (at least) some degree of control by the organization. Moreover, we define attributes to assign different weights (attribute `perceivedIntensity`, concept: SituationInfluence) and different probabilities (attribute `probablity`, concept: Situation) to different situations in order to mark their importance, cf. (Phadermrod et al. 2019). In turn, the attribute `justification` allows to justify for the assigned classification (e. g., why we consider something as a strength).

`Situations` may be linked to other `Situations` by different types of relationships: (1) `is_alternative_to`, which allows us to model situations arising from different alternatives in the same diagram. This is opposed to a typical SWOT analysis, whereby one has to draw a separate table for each alternative (which makes it difficult to compare alternatives); (2) `occurs_in_parallel_with`, which allows us to cluster Situations according to a logical grouping; (3) `CausalRelation`, which allows us to account for the fact that situations are not independent, cf. (Coman and Ronen 2009)[1] . To streamline the analysis, we differentiate in the concrete syntax between two types of causal relationships given the probability of occurrence (captured by the attribute `occurenceCertain` of concept CausalRelation): `results_in` and `may_lead_to`; and finally, (4) `is_part_of`, which refines an abstract situation into more detailed ones so that situations can be modeled as a hierarchy using the relation.

To establish a relation to GoalML, our meta model includes a GoalML concept `AbstractGoal`. Briefly, GoalML defines a goal as "a future state with certain properties, which should be achieved (by means of performing certain actions) in accordance with criteria set by certain stakeholders" (Köhling 2013, p. 190, translated from German). An `AbstractGoal`, then, represents an abstract class that contains all elements common to the two types of goals of GoalML: an Engagement Goal, whereby one explicitly specifies satisfaction criteria and the time frame in which the goal should be achieved (Köhling 2013, p. 190), and a Symbolic Goal, which is more generally stated than an Engagement Goal.

To account for the fact that depending on the goal in question the same situation can be differently classified, we introduce `SituationInfluence` as an Association Class with a set of relevant attributes. This is also in

[1] Please note that Coman and Ronen (2009) stress that evidence shows that especially weaknesses are often linked in cause-effect relationships.

line with BIM, wherein "[t]he same situation may be favorable for some organizational goals, represented via positive influence links on model concepts, but unfavorable for others, represented via negative influence" (Horkoff et al. 2014, p. 1018).

Furthermore, we enable connections to elements of other perspectives on an organization (e. g., organizational structures, business processes, and IT infrastructure) via the abstract meta type `EnterpriseImpact`. EnterpriseImpact contains attributes valid for establishing relationships with any DSML that expresses a perspective on an organization. In particular, to increase the semantics of those relationships, we benefit from the already mentioned resource-based view, and characterize those relationships with an additional set of attributes such as, (1) evaluation of an enterprise artefact as a resource that can be valuable, rare, imperfectly imitable, or non-substitutable; as well as (2) assessing the certainty of an evaluation and its justification.

In this paper, we explicitly elaborate on establising the relationship with the extended ITML (Kinderen and Kaczmarek-Heß 2018) to account for the influence of IT infrastructure of an organization. ITML focuses on the main IT artifacts in terms of both hardware and software concepts, and different relations between these. We have extended it with additional concepts particularly relevant to the smart grid domain, as well as made sure that the relevant attributes are accounted for. For instance, each concept is equipped with a set of attributes allowing to capture, e. g., their quantity, or cost. The location of different physical devices (e. g., smart meter, substation, servers) may be captured by the concept `Location`. More specifically, the abstract EnterpriseImpact concept is specialized into `ITImpact` and IT artifacts can be `involved_in` an `ITImpact` towards some `Situation`. It is worthy noticing that `ITImpact` has attributes that are relevant for IT infrastructures specifically. For example, it is possible to assign a role to an IT artifact in a given situation. Here, we differentiate the role by referring to the classifications pointing to the role of information system in innovation processes (e. g., enabler, capability, cf., Hanelt et al. 2015).

Finally, in order to enable charaterizing strategic factors using performance measures, a link between Situations/SituationInfluence and Indicators, as defined in MetricM, (Strecker et al. 2012), may be introduced.

5.3 Implementation in ADOxx

To ensure that the created models are consistent with the underlying language specifications, we extend the corresponding tool for modeling with MEMO, called MEMO4ADO (Bock and Frank 2016), which in turn is based on the meta modeling software environment ADOxx (Fill and Karagiannis 2013). The extended MEMO4ADO version features new concepts, relations as well as new diagram types. We use the extended MEMO4ADO to model the case scenario presented in Sect. 7.

Tab. 2 shows an exemplary concrete syntax that has been defined within the extended MEMO4ADO. As our aim is to ensure the intuitiveness of concrete syntax, we use well-established guidelines from Moody (2009) for designing cognitively effective visual notations (i. e., notations that are optimized for processing by the human mind). These guidelines include, among others, Semiotic Clarity, Perceptual Discriminability and Semantic Transparency. In particular, the Semantic Transparency guideline, which implies that the meaning (semantics) of a symbol is clear (transparent) from its appearance alone (Moody 2009), has a strong influence on our design (cf. Tab. 2). We consider the use of an intuitive, domain-specific graphical representation important, as it should allow domain stakeholders to grasp the idea without a long learning process.

The introduced extensions result in changes in already existing diagram types and give rise to the definition of new ones. The diagram types currently offered by the tool and used in the strategic analysis are listed in Tab. 3.

Table 2: Examples of the SAML Concrete Syntax

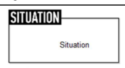
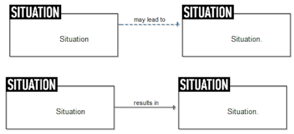
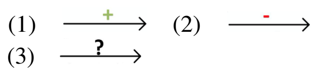
Symbol	Explanation
	Situation
	Alternative situations
	Examples of causal relationships between situations
	Visualization of influence: (1) positive (supports), (2) negative (hinders), (3) not yet determined, between goals
	Various examples of visualization of possible SWOT classifications and their perceived probability
	Involved in relationship allowing to link relevant artifacts (e. g., IT) and situations

Table 3: Diagrams

Perspective	Exemplary Diagrams
Business Context Analysis	Organizational Structure Diagram, Goal Diagram, Business Process Map
IT system understanding	IT Infrastructure Diagram
Strategic analysis	Strategic Analysis Diagram

6 Method

As already explained, the proposed modeling method should enable (a) a *strategic fit analysis* by supporting problem structuring and strategic assessment of (a set of) digitalization initiatives or of different alternatives for one planned digitalization initiative; (b) a *rationalization* for the strategic decisions made when assessing possible digital initiatives or alternative ways they may be implemented.

In order to define the method, we have considered, among others, the following: (1) general literature on performing strategic analysis and ways typical SWOT-analysis workshops are conducted, e. g., (Chermack and Kasshanna 2007; Leigh 2010), as well as dedicated methods, e. g., (Chang and Huang 2006; Coman and Ronen 2009; Phadermrod et al. 2019; Valentin 2001); (2) root-cause analysis procedure; and finally, (3) reasoning maps as used in the operations research differentiating between a divergent phase and a convergent phase.

Leigh (2010, p. 115) argues that although a SWOT analysis should be "a process by which a group of stakeholders (a) identify internal and external inhibitors and enhancers of performance, (b) analyze those factors based on estimates of their contributions to net value and approximations of their controllability, and (c) decide what future action to take with regard to those factors", quite often organizations carry out only the first of these three tasks, cf. also (Hill and Westbrook 1997). To address this shortcoming, the main elements of our method (presented in Fig. 2) encompass four main steps: Step 1: Defining scope, objectives and context of analysis, Step 2: Identification of relevant factors, Step 3: Conducting strategic fit analysis by relating internal and external factors, and Step 4: Acquiring information for the needs of decision making. However, please take note that because of the emergent property of strategies, cf. (Mintzberg et al. 1998), strategic analysis supported by tools cannot be "boiled down to a few simple steps that work in any situation". As a consequence, the proposed process model should be seen merely as a suggestion of how the analysis could be conducted, and not as a stringent process one needs to strictly follow.

We start by *Step 1: Defining scope, objectives and context of the strategic analysis*. In line with Chermack and Kasshanna (2007, p. 388) having a common understanding of what is to

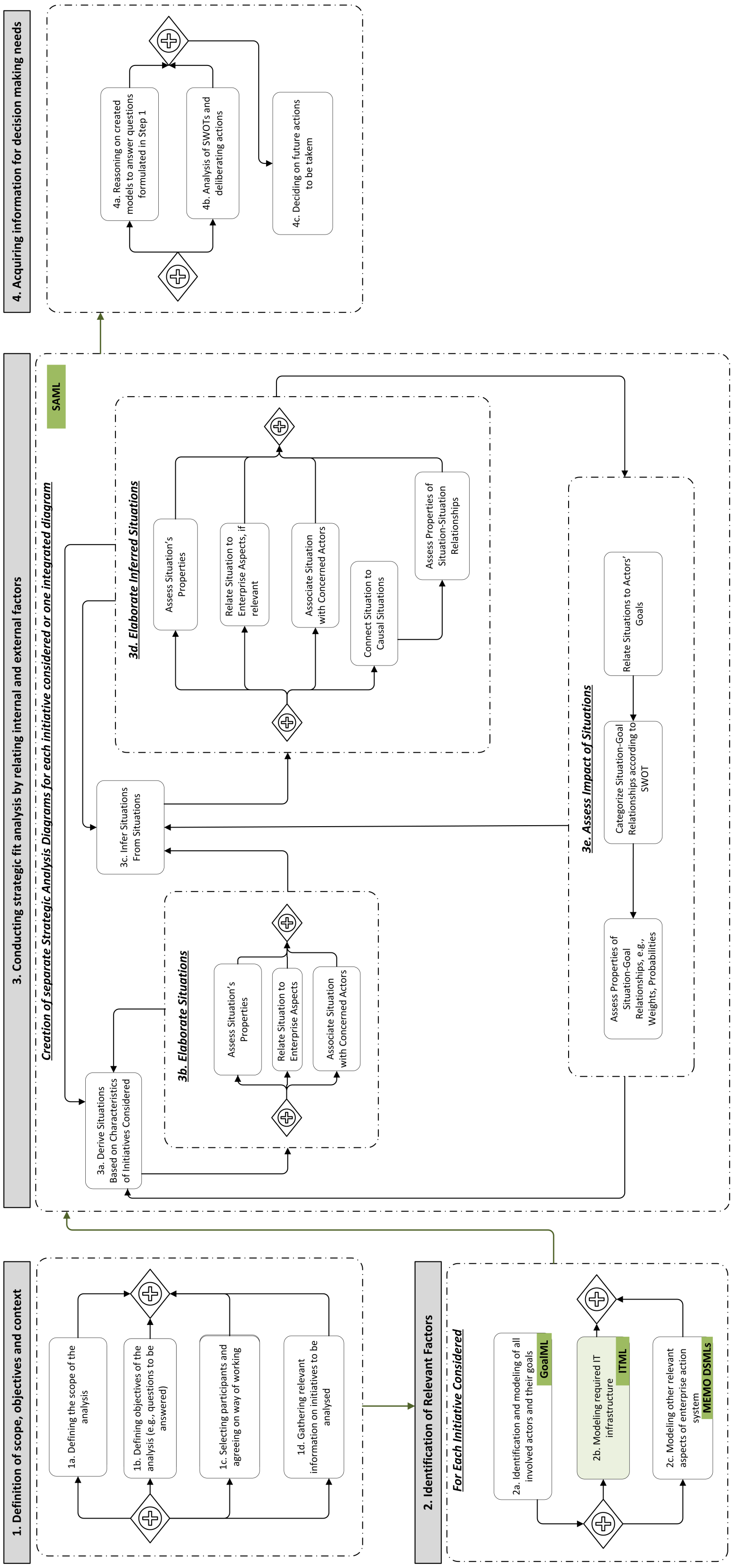


Figure 2: A modeling method for Strategic Analysis with SAML

be achieved by means of the strategic analysis is crucial. Therefore, as the first step the scope of the strategic analysis needs to be defined (Step 1a). Here we need to define what is to be analyzed (e. g., a set of possible initiatives or alternative implementations) and for whom. Next, the definition of objectives as well as specific questions to be answered follows (Step 1b). Considering the range of scenarios supported by the method, exemplary objectives of the strategic analysis may be: (1) obtaining understanding of internal and external factors being supportive or unfavorable to achieving goals of an enterprise through planned set of projects; or (2) gathering information required for the needs of deciding which one of the considered digitalization initiatives should be implemented taking into account strategic goals of an enterprise to be realized, or (3) deciding on the alternative configuration (e. g., in terms of IT assets to be used) of planned digital initiative taking into account strategic goals to be achieved.

Ideally, strategic analysis should be an iterative and participatory process (Leigh 2010). It is important to involve actors at varying levels of the organization to account for different perspectives (e. g., management, IT). Therefore, within the next activity (Step 1c), the set of actors participating and carrying out analysis, as well as the way of working (e. g., focus group), needs to be defined.

Finally, relevant information on the initiatives to be analyzed need to be gathered (Step 1d). Elicitation of required information can be accomplished through study of available documentation, interviews, focus groups, or interdisciplinary workshops, cf., (Chermack and Kasshanna 2007; Helms and Nixon 2010). The aim is to collect objective and quantified data required for the needs of comparing different initiatives or assessing characteristics of considered situations.

Once a common understanding have been reached, *Step 2: Identification of relevant factors* for each initiative should take place. Here, we suggest to start with considering all relevant actors involved (i. e., stakeholders, e. g., customers, competitors, government), and their goals (Step 2a). To this aim, one could use *Goals-Actors Diagrams* modeled using extended GoalML (cf., Kaczmarek-Heß et al. 2018). Indeed, strategic fit analysis (to be done in Step 3) should be complemented with a clear statement of the goals of the organization itself, as well as all involved stakeholders, as a frame of reference, cf. (Kotler 2000). Then, the focus should be assigned to elements of enterprise action system and information system. In line with the focus of this paper, we explicitly account for information technology (IT) infrastructures in the method and in the following demonstration. However, this is in no means to neglect the relevance and importance of other aspects of enterprise action systems.

The elements of IT infrastructure are modeled using an *IT Infrastructure Diagram* created with the extended ITML (cf. Kinderen and Kaczmarek-Heß 2018) (Step 2b). Other elements of enterprise action system to be considered (Step 2c) are modeled using dedicated modeling languages belonging to MEMO and being guided by their respective methods (e. g., for business processes the OrgML modeling language would be used to create a *Business Process Map*).

Next, *Step 3: Conducting strategic fit analysis by relating internal and external factors* follows. It is driven by (1) systematically exploring the space of possible influences, as usually done within the typical root-cause analysis; and (2) intertwining divergent and convergent phases taking advantage of defensive and offensive assessment, as proposed by Valentin (2001).

Regarding the former, we start our analysis by defining main situations taking into account characteristics of considered initiatives modeled in Step 2. Then, we continue by systematically deriving next situations (e. g., that may be caused by an occurrence of initial situations), and elaborating on their characteristics and on relationships between modeled situations. We do it all in an iterative manner. In order to identify relevant situations, in addition to brainstorming, various checklists, as proposed e. g., by Kotler (2000) may be used. In addition, the guidelines and methods, e. g., the event-factor review, proposed by Coman and Ronen (2009), we consider to be helpful.

Regarding the latter, inspired by reasoning maps from operations research (see, e. g., Montibeller et al. 2008, p. 577), two phases are accounted for: (1) a *divergent phase* for problem structuring, whereby different internal and external factors are related to each other by identifying situations and assessing their properties, and (2) a *convergent phase* for qualitative assessment of the different relations, in terms of their weight (e. g., the strength of a certain positive or negative influence), and the certainty of an influence (e. g., *results_in* versus *may_lead_to*) takes place.

The main analysis within this step is conducted by creating a *Strategic Analysis Diagram*. The diagram allows to analyze situations (Step 3a), their characteristics (Step 3b), deriving new situations (Step 3c), elaborating relationships between situations (Step 3d), and assessing impacts of situations on goals (Step 3e). While elaborating on properties of situations, the already gathered (and modeled) information is used. For instance, we relate situations to stakeholders, IT Infrastructure, or other relevant aspects of enterprise action system (Step 3b). The analysis continues by identifying related situations (Step 3c) and elaborating on those (Step 3d). In the final step, the assessment of the impact of situations on defined goals takes place (Step 3e). Please note that as divergent and convergent phases have a recursive nature, those different steps may be conducted at will and it is possible to go back to previous steps at any point of time.

In practice, the number of relevant situations to be considered, as well as their impacts and influences may be extremely large. Therefore, to allow for scalability and foster understandability, it is suggested to consider creating a separate diagram for each initiative or for a subset of those. Nevertheless, a creation of one integrated diagram is also possible.

Although the construction of a strategic analysis model already may be used for clarification and communication purposes, the main value of those models come from the capability to support decision making process by providing answers to questions of interest. Therefore, the final step of the method encompasses *Step 4: Acquiring information for the needs of the decision making*. Please note that the type of information required differs and depends highly on the objectives defined for the analysis. Thus, depending on the objectives pursued, the information may vary, e. g., from the identification of the initiative being (with the highest probability) the most supportive to achieving objectives of an enterprise, through information on situations we should control, to gaining a general understanding of the dependencies between various aspects.

In any case, in order to provide the desired information, different types of reasoning approaches over the created diagrams can be applied (Step 4a). For instance, both bottom-up and top-down reasoning are possible. Regarding the former, given information about situations and domain assumptions, one may observe how this input propagates to other elements of the model. Regarding the latter, one may check whether there is an initiative (or a set of those) that provides satisfaction to a set of desired goals. Although the application of both quantiative and qualitative reasoning is aimed at, for now only the qualitative one is fully supported. Depending on whether we are dealing with complete model (complete information), reasoning approaches similar to those applied in BIM, cf. (Horkoff et al. 2014), Goal Model Reasoning, e. g., as described by Giorgini et al. (2003), or Probabilistic Decision Analysis may be applied. Such automated analysis is currently not implemented in the supporting tool.

Please note that in addition to selecting, e. g., the scenario of choice, analysis of the created models should also allow for deliberation and answering questions such as what are the consequences of ignoring threats and weaknesses, how strengths may be leveraged to realize opportunities, how threats can be turned into opportunities, or how can we leverage weaknesses into strengths, cf., (Kotler 2000; Leigh 2010; Valentin 2001).

Thus, a careful analysis of created models should allow decision-makers to determine which SWOTs to act on and how (Step 4b). Finally, future actions to be taken (Step 4c) should be agreed upon (e. g., selection of an alternative to be implemented, or a need to gather further information). Indeed, the identified factors give an insight into the importance of individual components within the enterprise, and thus, may be used as a starting point for creating a strategic plan, and allow decision makers to initiate appropriate action.

7 Illustration: Strategic Analysis of NRGcoin

To illustrate the proposed modeling method, we consider the strategic analysis of the NRGcoin initiative developed within an European public-private partnership project[2] . The NRGcoin initiative defines a blockchain-based support policy to better reward production and local consumption of renewable energy. It overcomes the drawbacks of incentive mechanisms applied to date, e. g., net metering (NM) or feed-in tariff (FiT), which according to previous studies (Mihaylov et al. 2019) can lead to problems such as overconsumption, overpayment, and stress on the electricity grid. A new crypto currency called NRGcoin is designed in the initiative as the medium of exchange of renewable energy (Mihaylov et al. 2015).

7.1 Definition of Scope, Objectives and Context

The NRGcoin initiative is planned to be tested within a microgrid, called the NRGcoin pilot, which consists of the following participants: (1) *DSOs*, distribution system operators, who provide, maintain, and manage the distribution network for renewable energy; (2) *consumers* who consume local green electricity and benefit from a cheaper price; (3) moreover, consumers can install renewable energy sources (such as roof-top solar panels) to also produce electricity themselves, and subsequently become *prosumers*.

To date, green electricity produced by prosumers is not traded directly with local consumers, but rather via an intermediary (such as retailers or utilities), who are sometimes supported by government subsidies. In order to gain more autonomy and to reduce costs, participants are looking to establish a local renewable energy economy through the use of NRGcoin. In previous work, cf. (Kaczmarek-Heß et al. 2018), the following advantages of NRGcoin initiative have been described: (i) the share of green energy consumption is increased because consumers can purchase green energy at a fixed rate of NRGcoin; (ii) self-consumption is promoted for prosumers because injection that does not match local demand will not be rewarded; (iii) stress on DSO grids is relieved because local demand is met by local supply and extra supply is self-consumed by prosumers, hence, there is less energy that needs to be transferred further up to the grid; (iv) operational costs are reduced because most of the daily operations are automated with the help of smart contracts; and last but not least, (v) no dedicated budget from the government is needed any more because incentives to both green energy consumption and green energy production come from NRGcoin itself.

According to the NRGcoin initiative, green electricity generated by prosumers can either be sold or self-consumed. For selling, prosumers inject locally produced electricity into the distribution network, which can then be withdrawn by potential consumers in the same neighborhood. Consumers pay one NRGcoin for each kWh of consumed green electricity, regardless of the fluctuation of electricity price in fiat market. The revenue from consumers is partly used to pay DSOs for grid costs and fees, partly for rewarding prosumers. At the end of every 15-minutes time slot, the amount of electricity that was injected by prosumers and actually consumed by consumers in that time slot, is rewarded with NRGcoins. Any excessive injection beyond that amount is not rewarded, which encourages prosumers to consume their own electricity. Consumers buy NRGcoins from a coin market in which prosumers and DSOs can sell their earned NRGcoins (Mihaylov et al. 2018).

The operation of the NRGcoin initiative relies on three pieces of software: (1) the NRGcoin smart contract application that runs on the blockchain to enforce the NRGcoin protocol as described above;

[2] http://nrgcoin.org/

(2) the wallet application that is in charge of NGR-coin income and expenditure; and (3) the order book application that matches sell and buy orders for NRGcoins exchange market. Meanwhile, during the execution of the NRGcoin initiative, three types of transactions take place: (1) electricity consumption (and resp. injection) transactions that record the amount of electricity being withdrawn (and resp. injected), (2) NRGcoin payment transactions that record: the NRGcoins being paid to the DSO for using the electricity grid infrastructure, the NRGcoins rewarded to prosumers for their injections, and the NRGcoins charged to consumers for their consumption; (3) NRGcoins trading transactions that record how NRGcoins are exchanged in the coin market against fiat currencies.

A tamper-proof ledger as the one offered by a blockchain serves as a good potential mechanism to record these three types of transactions. Blockchain ledgers are distributed among the nodes that participate in the network. Transactions are organized in blocks that are chained up into blockchains. Every node in the network has access to the whole history of the transactions and can check the validity of the blocks and transactions. Lacking a central authority to keep track of, validate, and write new records in such a distributed ledger, blockchain-based solutions make use of "consensus mechanisms" to reach agreement among nodes as to who will validate the transactions, create the next block, and broadcast it to the rest of the network (Xu et al. 2017).

In this paper, we carry out a strategic analysis on behalf of the NRGcoin pilot participants (namely DSOs, prosumers, and consumers), to analyze (1) existing consensus mechanisms, (2) their fitness to the current set up of the microgrid, (3) their implications for the long term goals of the microgrid, and (4) the influence on and the influence received from other stakeholders (such as government, blockchain provider), in terms of the technical characteristics of respective consensus mechanisms. More specifically, we mainly consider two protocols for reaching consensus: Proof of Work (PoW) and Proof of Stake (PoS).

The decision as to which consensus protocol (PoS versus PoW) to use is important, because the protocols exhibit differing characteristics, which directly or indirectly impact the achievement of participants' goals.

7.2 Identification of Relevant Factors

We start by identifying and modeling all involved actors (NRGcoin pilot participants and other stakeholders) and their goals (Step 2a), that one needs to consider when selecting a consensus protocol for the NRGcoin ledger (captured in Fig. 3).

The choice of the consensus protocol should be in line with the general EU energy policy that calls for sustainable solutions (G0). According to Prindle et al. (2007), two main elements of a sustainable energy policy are "Energy Efficiency" (G1) and "Motivate Production and Consumption of Renewable Energy" (G2). As we mentioned, the aim of the NRGcoin pilot participants is to set up a local renewable energy trading community among them (G3), which is aligned with G2. Effective operation of the local green energy community, on the one hand, calls for social responsibilities of the participants (G4), and, on the other hand, requires sufficient financial incentives to attain participants (G6). Moreover, the participants have also concerns regarding the technologies applied, which are required to be reliable (G7), and regarding the necessary investment, which should be modest (G8). Finally, from a practical point of view, the 15-minutes time interval for rewarding prosumers should be respected, which implies a timely validation of transactions (G5).

In this example, we show how the respective IT infrastructures underlying the PoW and PoS protocols contribute to the fulfillment of these goals (depicted in Fig. 3) in the context of a strategic analysis. To that aim, we model the respective IT infrastructures required by the two alternative consensus protocols in ITML as depicted in Fig. 4a for PoW, and in Fig. 4b for PoS (Step 2b). Although the achievement of the aforementioned goals can also be examined from other relevant perspectives of the NRGcoin microgrid (Step 2c), we only illustrate the influence of the IT infrastructure on

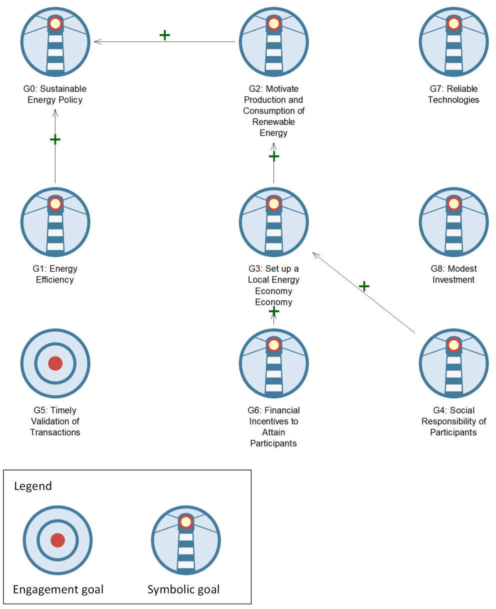


Figure 3: NRGcoin Initiative Goals modeled using adjusted GoalML

the actors and their goals. Other perspectives can be modeled and analyzed in a similar manner, with other MEMO modeling languages and their connection to SAML.

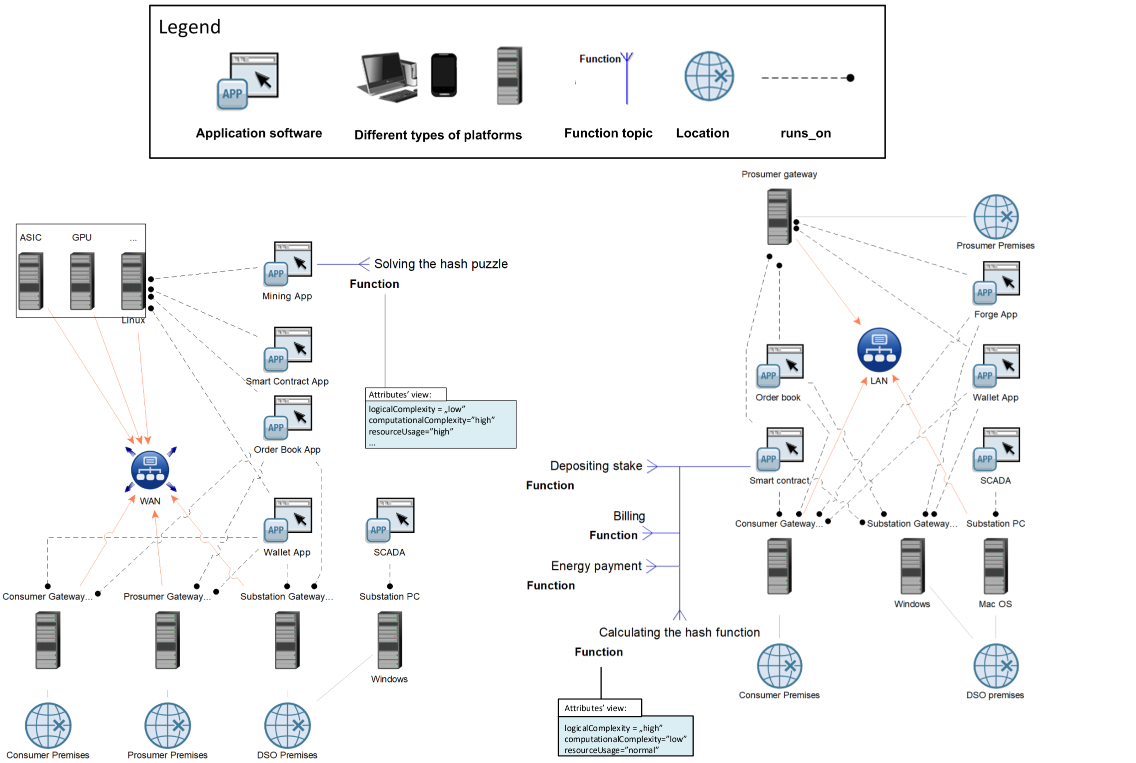
PoW (cf. Fig. 4a) is a pure cryptography consensus protocol whereby so-called miners interested in becoming the creator of the next block compete to solve a cryptographic puzzle (Xu et al. 2017). The first miner that finds the correct solution to the puzzle will become the creator of the next block. This miner will be rewarded with new coins (referred to as mined coins) and earns also fees associated with the validated transactions. Because the computation complexity of solving the cryptographic puzzle is high, specialized hardware such as ASIC, GPU is necessary for the creation of blocks. Moreover, a gateway device (in addition to smart meter and/or substation) is required at the premise of prosumers, consumers, and DSOs. The gateway provides both communication and computation capability to enable interaction with the NRGcoin initiative, such as trading, spending, and earning NRGcoins, and communicating with the smart contract.

In turn in PoS (cf. Fig. 4b), blocks are said to be "forged" or "minted" instead of "mined". Candidates for the creator of the next block are referred to as validators. The probability for a validator to become actually the creator of the next block is proportional to the amount of coins the validator owns. The selected validator earns fees associated with the validated transactions. Since the PoS technique is prone to security issues due to its simplicity (BitFury Group 2015; ILNAS and ANEC 2018), various socio-economic counter-measures have been introduced. For example, validators can be requested to lock a certain amount of coins as a stake in a security deposit in order to become a candidate for the next block. If the selected validator conducts malicious behavior while validating the next block, this validator will be punished by losing the stake (economic measure). A similar punishment measure can also be put in place from a social point of view whereby the selected validator is required to sign the block she creates. If a peer node detects faults in the block and reports it to the network, the validator will be punished with bad reputation and will be forbidden to participate in future validations. In an extreme case, the node can even be expelled from the network. As a consequence, the algorithm for PoS to select the validator for the next block is more of a combination of both cryptography, social, and economical mechanisms.

7.3 Conducting Strategic Fit Analysis by Relating Factors

After modeling the respective IT infrastructure behind the two consensus protocols in ITML, we move on to analyze their strategic fit towards the achievement of the actor goals. We start the strategic analysis by eliciting possible consequences directly emerging from the respective IT infrastructures of consensus protocols (cf. Fig. 5), and model them as situations (cf. Sect. 5.2) in SAML.

In the IT infrastructure diagram of PoW, we find that the function topic "Solving the hash puzzle" is provided as a functionality of the "Mining App". This functionTopic has three attributes marking the three noticeable characteristics of the PoW

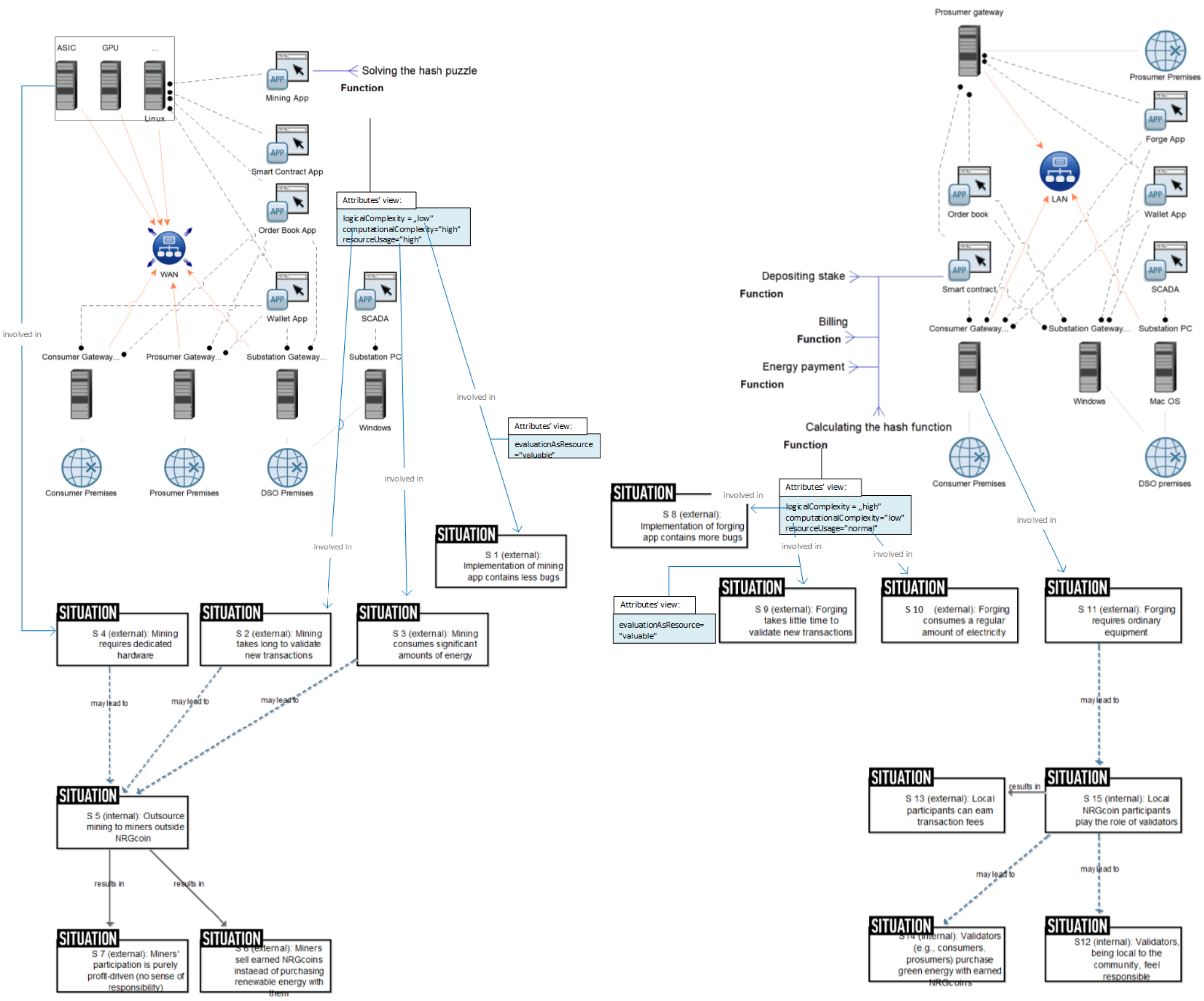


(a) PoW IT infrastructure overview *(b) PoS IT infrastructure overview*

Figure 4: IT Infrastructures of Alternative Consensus Mechanisms, modeled using extended ITML

protocol. On the one hand, as indicated by the first attribute logicComplexity = "low", the mining application is logically simple, because it only entails iterating the computation of a straightforward hash function on different parameters. On the other hand, as indicated by the second attribute computationalComplexity = "high", the mining application is computationally heavyweight, because the simple logic of PoW needs to be repeated many times until the right hash code satisfying a certain condition is found. Moreover, due to this high computational complexity, the corresponding resource needed to carry out the computation is also high, as marked by the third attribute resourceUsage = "high". This is especially the case when one increases the number of nodes in the blockchain to better de-centralize (Xu et al. 2017). These three attributes contribute to the following three situations (cf. Fig. 5a): as a consequence of low logical complexity, the implementation of the mining application may contain less bugs (S1); as a consequence of high computational complexity, mining can take long to validate new transactions (S2); and as a consequence of high resource usage, mining can consume big amount of electricity (S3). Furthermore, the resource use is also reflected in the underlying hardware required to run the mining application, which as visible in the IT infrastructure diagram, often runs on dedicated, resource-intensive hardware, such as GPUs (Graphics Processing Units) and ASICs (Application Specific Integrated Circuits). We identify the last observation also as a situation (S4) in SAML.

These situations are all external, because the NRGcoin pilot participants have no control over the design neither implementation of the PoW protocol, and are highly likely to occur. We connected these situations directly to the respective relevant



(a) Situations derived from PoW IT infrastructure *(b) Situations derived from PoS IT infrastructure*

Figure 5: Situations for IT Infrastructures of Alternative Consensus Mechanisms.

IT infrastructure elements via the SAML-ITML relation.

Considering that mining is a time-consuming and energy-consuming task, and requires dedicated hardware, the NRGcoin pilot participants (i. e., prosumers, consumers, and DSOs) may opt for outsourcing the task to a set of external miners (S5), as indicated by the relation “may lead to” between S2, S3, S4 and S5. As this situation follows from the decision of the NRGcoin pilot participants, it is categorized as an internal situation and the probability for it to take place is medium. Among others, we take note that situation S5 in turn has two implications (indicated by the relation “resultsIn”). Firstly, miners, being outside of the local energy grid, have no access to the green energy produced in the grid, hence would rather sell all earned NRGcoins than use them to purchase green energy for consumption (S6). Secondly, miners have no sense of belonging to the local renewable energy trading community, hence their participation in validating transactions and mining new blocks for the NRGcoin ledger is purely profit-driven (S7). Both S6 and S7 concern the behavior of miners, who are external to the NRGcoin pilot participants. Situations S6 and S7 are almost certain to happen if S5 takes place.

The second alternative to provide a consensus protocol is PoS. In contrast to PoW whereby the main function topic is to calculate the hash puzzle, extra function topics are necessary for PoS to penalize malicious behavior, to deposit stakes, and to sign forged blocks. Integration of these additional functionalities into the PoS application make its logic more complex (as indicated by the attribute logicalComplexity = "high"). However, this complex algorithm only needs to be executed once for each new block. Subsequently, the computational complexity of PoS is low, and the resource needed for executing PoS is in a normal range, (as marked by the second and the third attributes of "forge app"). Similar to PoW, these attributes contribute to the identification of the following situations (cf. Fig. 5b): as a consequence of high logical complexity, the implementation of the forging app may contain more bugs (S8); as a consequence of low computational complexity, forging takes little time to validate new transactions (S9); and as a consequence of normal resource usage, forging consumes regular amount of electricity (S10). Moreover, the forging app can run on the gateway devices of the NRGcoin pilot participants without needing dedicated hardware (S11).

Similarly, because the NRGcoin pilot participants have no control over the design neither implementation of the PoS protocol, situations S8–S11 are external and are highly likely to happen. We also connected these situations directly to the respective relevant IT infrastructure elements via the SAML-ITML relation. It is worth noticing that the connection between a situation and its corresponding IT infrastructure element can also be annotated in line with the resource-based view of the firm (cf. the meta model in Sect. 5). For example, being logically simple is a "valuable" property of the PoW protocol involved in situation S1, while being computationally simple is a "valuable" property of the PoS protocol involved in situation S9. Please note that in the previous version of this work, cf. (Kinderen et al. 2019), the latter was also labeled "rare" (in addition to "valuable"), because back then, PoS was still a novel thing (in comparison to PoW) and thus, was not yet widely adopted. However, with the development and usage of PoS (and its variants) in more and more blockchains nowadays, it is no longer the case hence is removed from this version.

Situation S11 gives the participants the possibility to play the role of validators themselves (S15, connected to S11 via a "may lead to" relation). S15 is an internal situation because it will follow the decision of the NRGcoin pilot participants (e. g., prosumers and consumers) as to whether or not to play the role of validators themselves. However, we can imagine S15 has a high probability to happen, because being the owner of the pilot project, the pilot participants are indeed interested in playing the role of validators so as to control and manage the NRGcoin blockchain when there is the possibility (according to S11). If S15 takes place, it has three implications: when NRGcoin pilot participants choose to perform the role of validators, they can for sure earn the transaction fees (S13, connected to S15 via a "resultsIn" relation), and we can largely rely on their inherent responsibility (S12, connected to S15 via a "may lead to" relation). Moreover, there is a good chance for the validators to spend the earned NRGcoins on purchasing locally produced green energy in this case because it is now physically and geographically possible (S14, connected to S15 also via a "may lead to" relation). Both S12 and S14 are decisions of the NRGcoin pilot participants who choose to play the role of validators. Hence they are internal situations. In contrast, S13 is prescribed as part of the PoS protocol, hence is external.

Up to this point, we have (i) identified direct situations emerging from the respective IT infrastructures required by the alternative consensus protocols, namely PoW and PoS, (ii) connected the direct situations with the corresponding IT elements with annotations when pertinent, (iii) inferred situations from direct situations following a root-cause analysis, and (iv) linked situations together with causal relation. In the following, we assess the influence of these situations towards the achievement of goals of the NRGcoin actors and categorize the influence as either a Strength, a Weakness, an Opportunity, or a Threat (SWOTs) (cf. Fig. 6). Note that one can also model the degree of intensity of a SWOT (i. e., a major Strength or a weak Threat), and/or the degree of certainty of the categorization following the provision of our meta model (cf. Fig. 1). Degrees exemplified below are measured with the scale provided by the SimpleAssessment class from the meta model.

Situation S1 takes note that the implementation of PoW contains less bugs. This is considered as a major opportunity towards the achievement of goal G7 because less bugs implies higher degree of reliability (hence the relation “Opportunity: high” between the two). Situation S3 takes note that mining consumes a significant amount of electricity, which makes PoW a less energy efficient solution (G1). In our models, we relate S3 and G1 with a “Threat: high” relation. Situation S2 takes note that mining takes on average long to finish, hence it likely causes delay to the validation of transactions hence poses a low Threat towards the achievement of G5. Situation S4 takes note that mining requires dedicated (and also expensive) hardware. This is in conflict with the goal of NRGcoin pilot participants to keep the investment modest (G8), hence constitutes a medium Threat. Nevertheless, if the mining is outsourced to external miners, namely if situation S5 takes place, participants can avoid such an expensive investment. Moreover, following the design of PoW, miners will be able to mine NRGcoins and earn transaction fees. From this point of view, S5 is positive towards the achievement of both G8 and G6.

However, S5 is not always a positive situation. Depending on which goals we are examining, it can also bring negative influence, as exemplified by the following analysis. Situations S6 and S7 are two consequences of S5 (following the root-cause analysis above and indicated by the “resultsIn” relation). Situation S6 takes note that external miners, because they have no access to the green energy produced within the community, would rather sell all earned NRGcoins than use them to purchase green energy for consumption. Therefore, this situation (being external) poses a medium Threat for “G2: Promote Production and Consumption of of Renewable Energy”. Situation S7 takes note that the participation of miners in validating transactions is purely profit-driven. Indeed, in order to control inflation, NRGcoins cannot be infinitely mined. Rather the amount of mined coins (i. e., coins created to reward miners) decreases over time. When it reaches the point where the profit of mining NRGcoins becomes marginal, miners will simply leave NRGcoin for other more profitable coins. This is a medium Threat towards “G4: Increasing Social Responsibility”. Note that the conventional SWOT analysis would fall short in demonstrating the dual role of S5 illustrated above, because it categorizes situations directly by putting them in one and only one of the four quadrants of a SWOT table. In our method, thanks to the separation between situation and situation influence, the categorization is rather done with respect to the relation between a situation and a goal, to account for the fact that depending on the goal in question, the same situation can be differently classified.

In a similar fashion, PoS situations can also be analyzed to determine their degree of influence towards achieving the goals of NRGcoin actors. Firstly, situations S8 and S10 represent Threats to goals G7 and G1 respectively: Situation S8 takes note that forging app has a higher chance to contain software bugs (due to its logical complexity). This is considered as a medium Threat towards the achievement of “G7: Reliable Technologies”; Situation S10 takes note that a forging app consumes regular amount of electricity. Although the consumed electricity by PoS is of a much smaller magnitude compared to the case of PoW, it is still extra consumption. Therefore, we consider S10 represents a low Threat to achieving energy efficiency (G1). Secondly, situations S9, S11, and S13 represent Opportunities towards the achievement of goals G5, G8, and G6 respectively: According to S9, PoS takes little time to validate new transactions. Therefore, it can almost be guaranteed that the 15 minutes time interval required by the NRGcoin mechanism will be respected. We mark this as an important Opportunity to the achievement of G5 (via a "Opportunity: high" relation); Situation S11 takes note that the forging app only requires ordinary computing equipment to execute. As depicted in the respective ITML model, NRGcoin pilot participants can simply make use of the gateways for this purpose (which they will anyway invest in for running the NRGcoin initiative). No additional investment is needed hence this is a "Opportunity: high" for maintaining the investment modest (G8); Running the forging app on their gateways, NRGcoin pilot participants (e. g., prosumers and consumers) play the role of validators for PoS. Situation S13 takes note that in such a case, NRGcoin pilot participants can also earn transaction fees. Although the main purpose for them to adopt NRGcoin is not for making money (but rather to have the possibility to trade green electricity freely without the intervention of an intermediary as we mentioned above), such an additional income would definitely provides extra incentive to attract and attain participants. We mark this as a "Opportunity: high" for achieving G6. Finally, the two internal situations S12 and S14 both represent Strengths to goals G4 and G2 respectively: On the one hand, following the reasoning above, NRGcoin pilot participants are now validators themselves (S12. They have the inherent responsibility towards the operation and maintenance of the local renewable energy community enabled by NRGcoin. This demonstrates a "Strength: high" to goal G4; On the other hand, there is a high chance for the validators to purchase local green electricity with the NRGcoins they earn by validating transactions (S14) for many reasons, such as the local green electricity if cheaper and locally available, or by doing so they also contribute to boost their own micro energy economy. This will result in higher percentage of green energy consumption and motivates prosumers to produce more green electricity to meet the increased demand, hence is a "Strength: high" towards goal G2.

7.4 Deliver Information for Decision Making

A rough estimation of the goal achievement following the strategic analysis above indicates that PoS supports better the goals of the stakeholders from the IT perspective: among the 8 discussed influences of PoW situations on goals, only 3 of them are positive (37.5%); while among the 7 illustrated influences of PoS situations on goals, 5 are positive (71.4%). A closer look at the respective properties of the influences make us realize that the distance is actually even more than just 71.4% vs. 37.5%: indeed, all the 5 positive influences of PoS are marked with intensity "high" (namely they are all strong strengths and/or opportunities); while among the 3 positive influences of PoW, only 1 is of "high" intensity, the other two are both "medium".

In case of PoS, two situations, "S9: Forging takes little time to validate new transactions" and "S11: Forging requires ordinary equipment", are worth mentioning. They constitute the root cause of all the positive influences of PoS, because all the situations that bring a positive influence in case of PoS are derived from these two situations following the root cause analysis. In turn, situations S9 and S11 are the consequence of the two inherent properties of the "Forge app" (namely low computational complexity and ordinary hardware requirement) of the PoS protocol (as indicated by the "involvedIn" relations between the situations and the corresponding IT infrastructure elements). Following this straightforward reasoning, one might draw the conclusion that the competitive advantage of PoS merely originates from the nice design and implementation of the PoS protocol itself, which are beyond the control of NRGcoin pilot participants. However, there is more than that. The right decision of NRGcoin pilot participant as to whether or not play the role of validators themselves is also key. More specifically, to fully leverage the advantageous properties of the PoS protocol, it is also required that situation "S15: Local NRGcoin participants play the role of validator" will take place, because without S15,

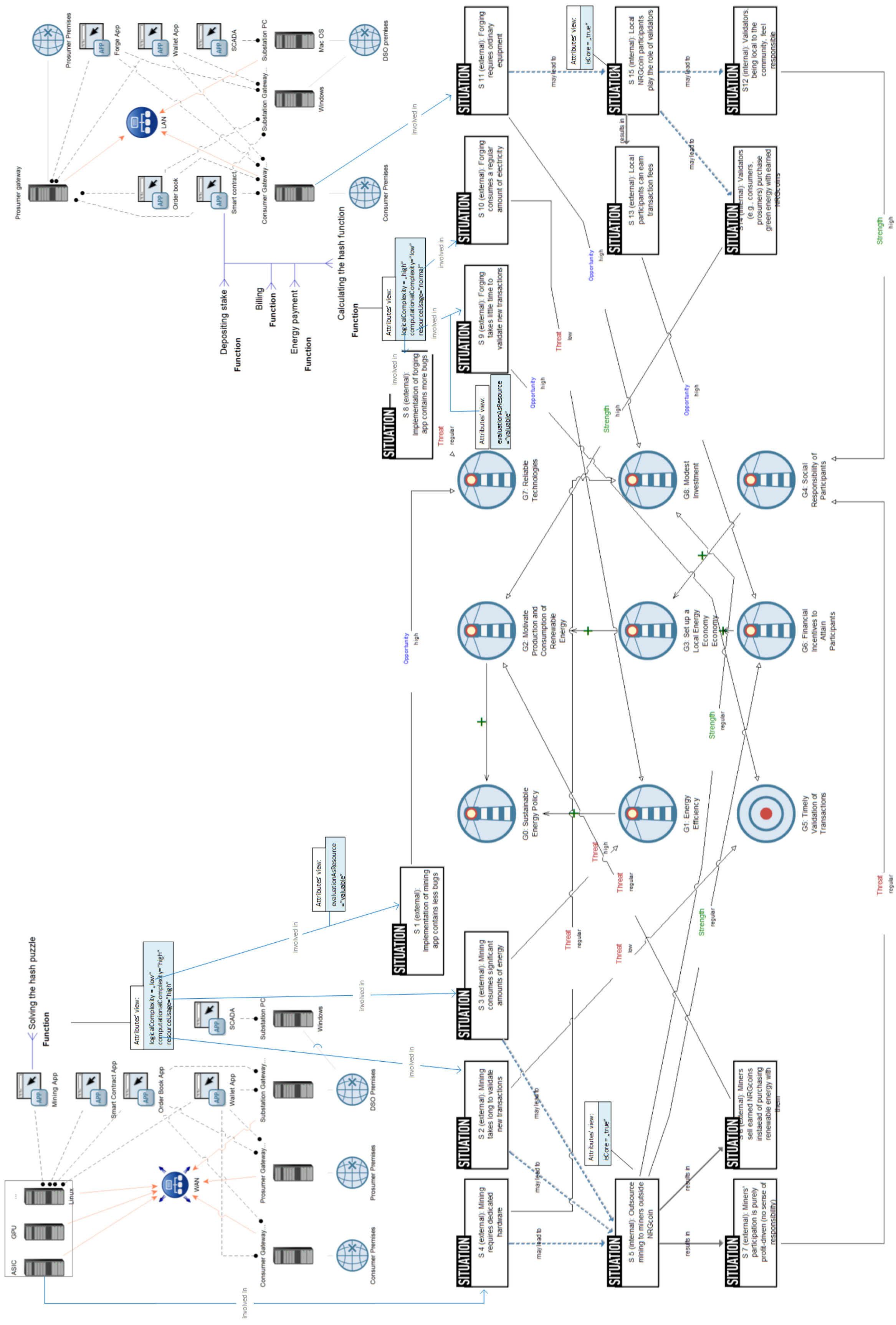


Figure 6: Strategic Analysis of NRGcoin: PoW vs.PoS

the three consequent situations: “S12: Validators, being local to the community, feel responsible”, “S13: Local participants can earn transaction fees”, and “S14: Validators purchase renewable energy with earned NRGcoins”, will not take place, either, neither will the 3 strong positive influences (towards “G4: Social Responsibility of Participants”, “G6: Financial Incentives to Attain Participants”, and “G2: Motivate Production and Consumption of Renewable Energy” respectively). In other words, if the NRGcoin pilot participants decide to choose PoS, it is also recommended to play the role of validators themselves. Outsourcing forging will bring similar issues as in the case of outsourcing mining for PoW, such as lack of responsibility of external validator, losing autonomy (discussed below), and external validators having no access to local green electricity. We exploit the “isCore” attribute of the Situation class in the SAML metamodel (cf. Fig. 1) to mark the importance of S15 (i. e., we set “isCore = true” a posteriori for S15).

In case of PoW, a similar advice also exists. The NRGcoin pilot participants are informed that in case of selecting PoW, there is an important subdecision to make as to whether or not outsourcing mining to a group of external miners. Outsourcing mining (S5) is the source of two positive influences of PoW (towards “G6: Financial Incentives to Attain Participants” and “G8: Modest Investment” respectively), but also is the cause of two situations (“S6: Miners sell earned NRGcoins instead of purchasing renewable energy with them” and “S7: Miners’ participation is purely profit-driven (no sense of responsibility)”) which bring negative influence (towards “G2: Motivate Production and Consumption of Renewable Energy” and “G4: Social Responsibility of Participants”, respectively).

Moreover, in case they favor the outsourcing, another iteration of the method as depicted in Fig. 2 will be needed. There will be some modifications to be introduced to the IT infrastructure models in order to further elaborate. For example, the network connection between miners and the other actors will be further specified as WAN (Wide Area Network) because miners are physically geographically located in a wide area. On the contrary, because the participants of the PoS network all physically located in the same neighborhood, it can make use of a local area network (LAN) connection for communication. These changes then in turn give rise to new situations. Just to name a few: WAN experiences more data transmission errors on average; WANs tend to be less fault tolerant because they are made of large number of systems; WAN is difficult and costly to maintain due to its wide geographical spread; WAN has low bandwidth and low speed; and WAN is out of the control of the microgrid. These newly recognized situations will also influence the achievement of NRGcoin actors goals. For example, the low speed will pose a problem for timely validation of transactions, hence is an extra threat to G5 (in addition to S2). One advantage of a microgrid (compared to a macrogrid) is that it can operate in both connected-mode and so-called “island-mode”. In island-mode, a microgrid can function autonomously, both physically and economically. The microgrid members, when switching to NRGcoin, of course do not want to lose the possibility to run the island-mode and to be self-reliant. However, in case of PoW and outsourcing mining, such an autonomy is simply impossible: the microgrid needs to be connected any way, not for energy transmission, but for communication. The goal of NRGcoin pilot participants to remain autonomous was not explicitly expressed in the first round of analysis, but emerges with the result of the analysis (see also Sect. 6 that acknowledges the emergent property of strategies).

Consequently, due to its key status, situation S5 is also marked with “isCore = true”.

8 Discussion

In this section, we first discuss to what extent our modeling method fulfills the requirements from Section 3. This is followed by a comparison to a general SWOT analysis, to further emphasize where the added value of our modeling method lies.

Table 4: Requirements Fulfillment – Summary

R	*Requirement Description*	*Explanation*
1	Modeling strategic factors and expressing their qualities for the needs of strategic fit analyses.	Strategic factors are conceptualized by means of (1) the "Situation" concept and its associated qualities, and (2) importantly the concept "SituationInfluence", which allows for expressing a strategic factor relative to organizational goals.
2a	Accounting for concepts from approaches complementary to SWOT.	We use a set of attributes from the resource-based view on the firm, as well as Porter's five forces and various categories from the telescopic observations framework.
2b	Enabling differentiation among elements belonging to strategic analysis by considering their importance, e. g., through accounting for weights or probabilities of occurrence.	As a first step we introduce the attribute "isCore:boolean" for both "Situation" and "SituationInfluence" and to mark out important strategic factors. Similarly, for both concepts we introduce an attribute to express probabilities, like "probability:Assessment" for "Situation".
2c	Providing support for explanation and documentation.	"Situation" has an attribute "Justification". Next to that the relation of strategic factors to other elements of the enterprise action systems, which is inherent to our modeling method, allows for a systematic grounding of said strategic factors.
2d	Using performance measures to characterize strategic factors.	As can be seen in the scenario, we currently mostly rely on a combination of root-cause analysis and strengths of relations to a posteriori mark out the most pertinent strategic factors. Further performance measures and associated reasoning capabilities are foreseen as part of future work.
3	Accounting for a rich set of relationships.	Relationships, with associated semantics are present to express (1) a SWOT relation to organizational goals, as stated via the concept "SituationInfluence", (2) a relation of "Situation" to the underlying IT infrastructure elements, via the concepts "EnterpriseImpact' and "ITImpact".
4	Accounting for context-specific classifications.	As stated, we express SWOTs relatively to other concepts, especially with respect to organizational goals. This allows us to make strategic concepts context-specific: a situation may a strength relative to one goal, but a weakness towards another.
5	Analysis of strategic factors needs to be complemented with a clear statement of goals of involved stakeholders as a frame of reference.	As stated before, our modeling method caters for an explicit relation of strategic factors to organizational goals.
6	Relating concepts for strategic analysis particularly with IT concepts, and with other elements of an enterprise action system.	As mentioned under Requirement 3 above, we have a dedicated "EnterpriseImpact" concept, which for the relation to IT infrastructure elements is specialized into "ITImpact".

8.1 Requirements Fulfillment

Tab. 4 summarizes the fulfillment of our modeling method regarding the requirements identified in Sect. 3.

Firstly, at several points our modeling method allows for contextualizing strategic factors by means of a rich set of relations (cf. Requirement 3). This contextualization happens in two ways. On the one hand, relating situations (as states of affairs) to organizational goals (Requirement 5) allows for classifying a strategic factor as being a SWOT *relative* to an organizational goal (cf. Requirement R4). Morover, by establishing a trace between strategic factors and goals, our modeling method provides support for explanation and documentation (cf. Requirement 2c). On the other hand, situations are also related to other elements of the enterprise action system, with a focus on IT infrastructure elements (in line with Requirement 6).

Secondly, we provide a semantically rich specification of strategic factors (Requirement 1), especially in terms of an enrichment with concepts from approaches complementary to SWOT. This added semantic richness can facilitate analysts in their elicitation and classification of situations, e. g., by considering the resource-based view on the firm for IT infrastructure elements (cf. Requirement 2a). Also, the added semantic richness allows us to differentiate among elements of a strategic analysis (cf. Requirement 2b), particularly by marking out certain situations as being core, and stating the probability of occurrence.

8.2 Comparison to conventional SWOT analysis

To further emphasize the added value of our modeling method we now perform a strategic analysis using a conventional SWOT for the same, NRGcoin, scenario. We focus here on the SWOTs found for using proof-of-work as a consensus mechanism, as depicted in Tab. 5.

Taking the requirements for our modeling method as a point of departure, we find that a traditional SWOT analysis is lacking in the following ways: (1) a lack of semantically rich concepts (in line with requirements R1–R2). For example, different to our modeling approach the various SWOTs in Tab. 5 are merely factors organized according to one of the four quadrants. As such, they lack semantic richness in terms of, e. g., importance scores (cf. Requirement 2b), or complements to SWOT (cf. Requirement 2a). For example, using a conventional SWOT table, in the NRGcoin case we cannot express that miners' participation being predominantly profit-driven is a more pertinent threat than miners consuming electricity; (2) a lack of semantically rich relations. Returning to Tab. 5, we observe a lack of semantically rich relations (or any relation for that matter). Compared to our modeling approach this inhibits at least the following: a root-cause analysis among the various factors (in line with Requirement 3). e. g., whereas there exist a relation between the factors "Miners' participation is purely profit-driven" and "Miners sell earned NRGcoins instead of purchasing renewable energy with them" (see Fig. 6), in a conventional SWOT analysis this relation cannot be indicated. As such, one does not have analysis capabilities that come with a root-cause analysis, such as an assessment of what factors underlie others. In addition, the lack of (semantically rich) relations mean that we lack a grounding in different enterprise action system perspectives (cf. Requirement 6). Prominently, in what is currently emphasized in both our modeling method and the NRGcoin case, we lack a relation to the IT infrastructure perspective. Specifically, this means that any factors that are listed as part of the SWOT table, such as "Mining takes long to validate new transactions" lacks a grounding in characteristics of the IT infrastructure perspective (such as "computationalCompexity=high" for the software application "Mining app" as per Fig. 6).

To be fair, as argued in Sect. 2, SWOT analyses are mostly popular due to their simplicity, which can help brainstorming about positives/negatives with respect to internals and externals of an organization (Pickton and Wright 1998). As such, differentiated analysis of the kind that we have presented is not natively something that a typical SWOT analysis will support. Nevertheless, coming back to Sect. 2, and as illustrated in this section, given the serious lackings in SWOT regarding its ambiguous definition of key terms, and lack of ability to introduce relations (between factors, but also in relation to different perspectives), a complement is called for (such as provided by our modeling method).

9 Conclusions

In this paper, we have shown how enterprise modeling can support the strategic analysis of digitalization initiatives by using a combination of modeling languages, among others, SAML, for expressing strategic analyses, and ITML, for expressing IT infrastructure. Specifically, we showed how (1) SAML allows for explicitly relating strategic elements to each other, allowing

	Positive	Negative
Internal	*Strengths* • Outsource mining to miners outside NRGcoin • Implementation of mining app contains less bugs • Transparent mechanism for tracking energy exchange within the community	*Weaknesses* • Scalability issues connected with the implementation of the PoW algorithm • Lack of computational resources to enable PoW locally • Limited human capital that masters the technology
External	*Opportunities* • Possibility to address new markets and introduce additional products and services • Competitive advantage • Exposure and increased reputation for the community	*Threats* • Mining consumes significant amounts of energy • Miners sell earned NRGcoins instead of purchasing renewable energy with them • Mining requires dedicated hardware • Mining takes a notable amount of time to validate new transactions • Miners' participation is purely profit-driven

Table 5: SWOT analysis for using Proof of Work within NRGcoin

for root cause analyses, and how (2) the explicit relation of SAML to ITML can be used to contextualize elements of a strategic analysis. In terms of limitations, firstly, we notice that the produced SAML models quickly increase in complexity. While model complexity is not a novel phenomenon (goal models tend to have a similar issue), it should be addressed since it can inhibit the interpretation of the models, thus potentially limiting the promised analysis capabilities.

In addition, for future work we intend to extend the expressiveness of the used languages, and to extend the corresponding reasoning capabilities. In particular, this concerns extending the capability to mark out situations as important. Currently we mark this importance with the attribute "isCore:boolean". While this is a useful first step, for future work it would be good to provide (a) further expressiveness, in terms of a more differentiated importance score and a grounding for the importance score, and related to the grounding (b) an underlying reasoning mechanism for situations, e. g., pertaining to a root-cause analysis, and/or the intensity of associated SWOT relations. Also, in terms of reasoning capabilities, we intend to concretely incorporate performance measures (in line with Requirement 2d). Here, a first step is to make concrete the relationship with MetricM, mentioned in Section 5.2, which is dedicated to the conceptualization of performance indicators.

Related to the reasoning capabilities expansion, we intend to expand upon software tool support. Firstly, we intend to equip the ADOxx implementation with dedicated reasoning functionality, either by exploiting the native (querying) capabilities of ADOxx, or by establishing a link between models created in ADOxx and an external reasoner[3] . The aim would be to support quantitative analysis as done, e. g., in GORE; as well as to support the qualitative analysis based on relationships between situations. Secondly, regarding large SAML diagrams we consider supporting different types of filtered views, e. g., show only situations that are directly impacting goals, or to show only situations that are caused by a certain enterprise elements.

[3] Akin to the web-based simulation component for business processes expressed in ADOxx BPMN. This component is available on https://www.adoxx.org/live/adoxxweb-simulation-details (last accessed on 18-11-2020).

Finally, the strategic analysis presented in this paper can be perceived of as a first step in a more comprehensive analysis of a digital transformation initiative. Thus, as part of future work we intend to elaborate on other issues, such as a quantitative analysis of the associated costs and benefits, and on how these issues relate to the strategic analysis as presented in this paper.

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