Towards Formal Strategy Analysis with Goal Models and Semantic Web Technologies

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Abstract. An informed strategy-making process involves strategy analysis to determine the strategic position of the company. In this paper, we investigate the formalization of different frameworks of strategy analysis in order to facilitate the tasks of strategic management. The thus formalized strategic reports can be shared among employees and combined for more holistic analyses. Semantic web technologies serve as the technological foundation, which allows for the expression of strategic questions as queries over the models as well as an integration of external data sets from the semantic web.

Keywords: Knowledge management · Strategic management · Business modeling · SWOT · PESTEL · Porter's Five Forces · iStar 2.0

1 Introduction

Strategy analysis contributes towards an informed strategy-making process that ultimately secures the long-term viability of the company. Frameworks for strategy analysis serve for the identification and classification of the relevant factors for strategic decisions [5, p. 27], fostering an understanding of the company's strategic position that considers both external factors and the capabilities of the company [9, p. 11].

Goal models introduce a strategic element to conceptual modeling. As such, goal models are typically employed in early-phase requirements engineering and focus on *why* a planned system should behave in one way or the other [18]. The iStar 2.0 (i*) modeling language [4], for example, allows for capturing the actors that ultimately interact with the planned system as well as the goals and tasks that drive these interactions.

In this paper, we exemplify how goal models may be employed to formalize traditional frameworks of strategy analysis, e.g., SWOT, PESTEL, and Porter's Five Forces. The structured representation of strategic reports through goal models facilitates knowledge-sharing among employees and allows for a combination of strategic reports, e.g., from different departments over different time periods, to obtain more holistic analyses. Semantic web technologies provide the technological means for formalizing strategy analysis with goal models. Key technologies are the Resource Description Framework (RDF), RDF Schema (RDFS),

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the Web Ontology Language (OWL), and the SPARQL query language (see [6] for further information). Individual strategic questions – e.g., *What are the opportunities and threats for a particular company?* – can then be expressed as SPARQL queries and executed on different data sets. Furthermore, linked open data (LOD) published on the semantic web [15] could complement the knowledge about business situations.

The remainder of this paper is organized as follows. First, we briefly introduce strategy analysis and review related work. In Sect. 2, we then focus on representation of strategic reports using goal models. In Sect. 3, we focus on the use of semantic web technologies for further data analysis. We conclude with a discussion and an outlook on future work.

1.1 Strategy Analysis

Strategy analysis considers, on the one hand, the environment of the company and, on the other hand, the company itself [5]. Analysis of the environment typically consists of a study of the macro-environment followed by industry analysis [9]. Analysis of the company assesses the company's capabilities, a key instrument being value chain analysis (cf. [12]). The results of the analysis of both environment and company allow decision makers to determine the company's strategic position which, in turn, serves as an important input to making informed, rational strategic choices [9]. In this paper, we exemplify the concept of formal strategy analysis by focusing on frameworks for environmental analysis.

SWOT (strengths, weaknesses, opportunities, threats) analysis, as one of the basic analytical frameworks in strategic management, reflects the dual focus of strategy analysis on both internal and external factors of a company. Strengths and weaknesses capture the capabilities of the company. Opportunities and threats depend on the environment. Although criticized (see [5, p. 12f.]), SWOT remains a staple in the strategist's toolbox.

Apart from SWOT, more refined frameworks exist to analyze a company's environment. The PESTEL framework [9] breaks up macro-environment into political, economic, social, technological, ecological, and legal environment. For each PESTEL dimension, the analyst identifies a set of factors that determine a company's strategic position. Furthermore, Porter [13] famously identified five forces that characterize an industry: threat of substitutes, threat of new entrants, rivalry among existing competitors, as well as bargaining powers of suppliers and buyers. Both five-forces analysis and PESTEL can be part of an assessment of market attractiveness [8, p. 280].

1.2 Related Work

Related work [2,3] has investigated the representation of enterprise models using business model ontologies and semantic web technologies, with a focus on *enterprise model analysis*, i.e., checking validity against reference models and algorithmically analyzing the complexity of enterprise models. Similar to our work, the semantic web technologies RDF, RDFS, and OWL are used for the representation of business model ontologies. We, however, focus on strategic questions rather than constraint and validity checking – important tasks that could be adapted in order to construct a modeling tool and analysis client for strategy analysis.

The strategic business model ontology (SBMO) [14] adapts the i* framework for modeling a company's strategy, thereby focusing on goals, motivation, and intentions of the actors. Samavi et al. [14] position the SBMO as a methodology for requirements engineering. The rationale behind SBMO is obvious: A better understanding of the goals and intentions behind strategic actions will ultimately lead to better service design. As opposed to SBMO, we formalize strategy analysis in order to support strategy analysts rather than requirements engineers.

The business intelligence model (BIM) [7] aims at rendering business intelligence (BI) more accessible to average business users. Horkoff et al. [7] argue that current BI systems focus too much on the data in order for business users to effectively work with these systems. Business users hence expect the data models to be presented in familiar (business) terms, e.g., strategy, business models, business processes, risks. In this regard, BIM offers consolidation of the predominantly data-centric view in today's BI and the business-centric view of analysts. To this end, BIM represents goals, situations, and business processes besides the more data-oriented indicators. With our paper, we aim to position formalized strategy analysis based on goal models and semantic web technologies as a means to knowledge management in strategic management. We aim to make explicit the various strategic reports currently otherwise compiled in companies in the form of natural-language text. The thus formalized written reports can be more easily shared and combined across individuals and departments.

2 Goal Modeling for Strategy Analysis

The PESTEL dimensions of factors, e.g., political and ecological, for analysis of a company's macro-environment translate into i* actors with an actor boundary. Each of these actors represents an abstract real-world actor to be reckoned with. For example, the political dimension translates into an actor *Politics*, representing politics at large as a force of influence in the real world. Elements within the boundary of these actors represent the specific factors in the respective PESTEL dimensions. The actors that represent PESTEL dimensions may be refined via *participates-in* relationship into several other actors which represent relevant, more concrete real-world actors in the respective dimensions. Other actors represent more concrete real-world actors affected by the PESTEL factors, e.g., individual companies or types of companies. Elements within the boundaries of these other actors usually depend on the PESTEL actors' elements.

Figure 1 shows political and ecological factors of a PESTEL analysis of the airline industry's macro-environment. The example follows a case study of the low-fare airline Ryanair's strategic position [9] and is partially based on a PESTEL analysis of the airline industry [8, p. 56]. The political dimension, represented by the *Politics* actor, comprises national governments and the European

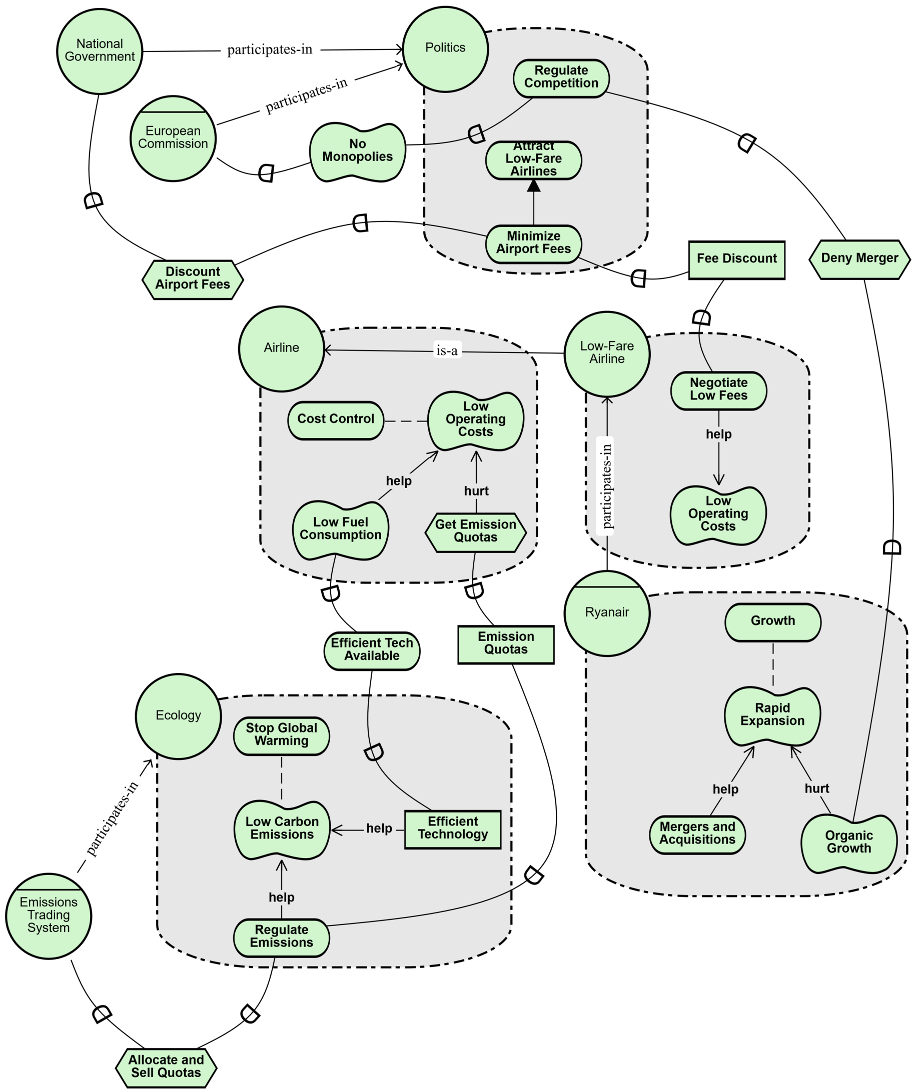

Fig. 1. Political and ecological factors of a PESTEL analysis of the airline industry's macro-environment, formalized using i* (case adapted from [9, p. 612ff.], model edited with piStar [11]). A circle denotes an actor, a dash-dotted circle attached to an actor denotes the actor's boundary. A circle with a horizontal line in the top half denotes an agent, i.e., a concrete actor. An ellipse denotes a goal, a hexagon denotes a task, a rectangle denotes a resource, a potato-shaped form denotes a quality which may be linked to a goal, task or resource by a dashed line. A connecting line with the letter "D" denotes a dependency. The direction of the "D" indicates the dependency's direction.

Commission as actors. Political actors intend to regulate competition (the European Commission) and attract more low-fare airlines (the national governments). Regulating competition, when the outcome is a denied merger, stimulates organic growth which, in turn, hurts rapid expansion – one of Ryanair's goals. Attracting low-fare airlines may be achieved through minimizing airport fees. Airport fee discounts granted by national governments help low-fare airlines achieve low operating costs. In the ecological dimension, represented by the *Ecology* actor, stopping global warming, qualified by low carbon emissions, is paramount and helped by more efficient technology and emissions regulation. Airlines depend on the Emission Trading System – an agent that is part of the ecological dimension – for acquisition of emission quotas which hurt the goal of low costs. More efficient technology, on the other hand, helps keeping costs low through lower fuel consumption.

In the proposed PESTEL modeling approach, modelers should identify for each actor several "primary" goals which are qualified by qualities that are contributed to by intentional elements that depend on factors in the various PESTEL dimensions. For example, in Fig. 1, Ryanair pursues growth as a primary goal, qualified as rapid expansion which is hurt by organic growth. Organic growth depends on mergers denied under politics' mandate to regulate competition. Actors may also inherit primary goals through is-a relationships and further qualify inherited goals. For example, an airline has cost control as a primary goal, qualified by low operating costs. Low-fare airlines negotiate low airport fees to keep costs low, which depends on politics' willingness to minimize fees and issue fee discounts in an attempt to attract more low-fare airlines.

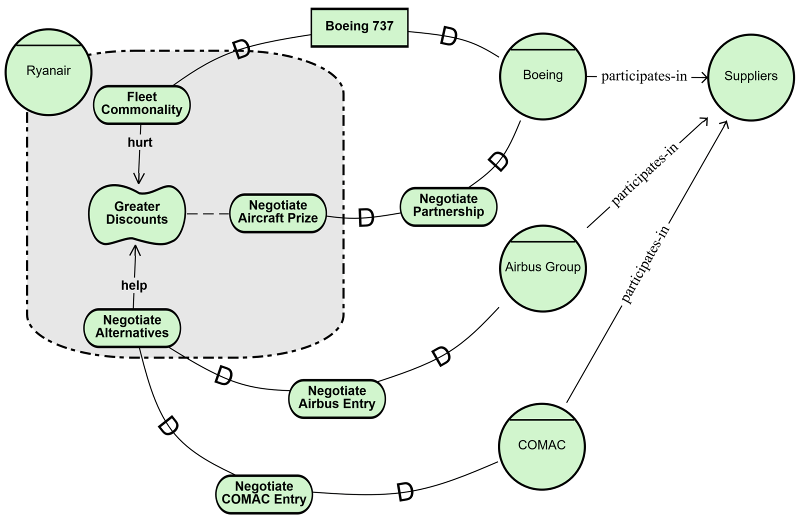

Fig. 2. Part of an industry analysis focusing on Ryanair's suppliers (case adapted from [9, p. 615f.])

An analysis of Porter's Five Forces requires identification of suppliers and customers, possible future competitors and potential substitutes. Similar to the PESTEL representation, each force translates into an i* actor representing the respective force, e.g., suppliers, as an abstract real-world actor which other actors participate in, representing more concrete real-world actors, e.g., Boeing, Airbus Group, and COMAC. Figure 2 illustrates the dependencies between Ryanair and its (prospective) suppliers modeled using i*. Ryanair commands a homogeneous fleet of Boeing 737 aircraft. The commitment to a single type of aircraft hurts the target of obtaining greater discounts during aircraft prize negotiations, since Ryanair's fleet commonality policy is publicly known. Establishing a credible threat of alternative suppliers, however, will increase Ryanair's leverage over Boeing to negotiate greater discounts.

3 Semantic Web Technologies for Data Analysis

We employ semantic web technologies to formalize strategic reports for use in knowledge-based systems. Figure 3 proposes an RDF representation for i*. The schema follows the iStar 2.0 metamodel [4, p. 14] but refrains from using reification in order to keep the graph structure of the RDF representation close to the visual representation. For example, depends-on is a property from an actor or intentional element to an actor or intentional element rather than a class as in the iStar 2.0 metamodel; domain and range of depends-on can only be represented in OWL (not shown). The RDF representation also introduces the related-with property as an abstraction of is-a and participates-in (Fig. 3, Lines 5 and 6). The absence of reification facilitates query formulation. Listing 1 then shows an RDF representation of the political dimension of the PESTEL analysis in Fig. 1; classes and properties that are defined in Fig. 3 have an `istar` prefix.

$\mathsf{Agent} \sqsubseteq \mathsf{Actor}$	(1)	$\mathsf{Task} \sqsubseteq \mathsf{IntentionalElement}$	(12)
$\mathsf{Role} \sqsubseteq \mathsf{Actor}$	(2)	$\mathsf{Resource} \sqsubseteq \mathsf{IntentionalElement}$	(13)
$\exists\mathsf{related\text{-}with}.\top \sqsubseteq \mathsf{Actor}$	(3)	$\exists\mathsf{contributes\text{-}to}.\top \sqsubseteq \mathsf{IntentionalElement}$	(14)
$\top \sqsubseteq \forall\mathsf{related\text{-}with}.\mathsf{Actor}$	(4)	$\top \sqsubseteq \forall\mathsf{contributes\text{-}to}.\mathsf{Quality}$	(15)
$\mathsf{is\text{-}a} \sqsubseteq \mathsf{related\text{-}with}$	(5)	$\mathsf{helps} \sqsubseteq \mathsf{contributes\text{-}to}$	(16)
$\mathsf{participates\text{-}in} \sqsubseteq \mathsf{related\text{-}with}$	(6)	$\mathsf{hurts} \sqsubseteq \mathsf{contributes\text{-}to}$	(17)
$\exists\mathsf{wants}.\top \sqsubseteq \mathsf{Actor}$	(7)	$\exists\mathsf{needed\text{-}by}.\top \sqsubseteq \mathsf{Resource}$	(18)
$\top \sqsubseteq \forall\mathsf{wants}.\mathsf{IntentionalElement}$	(8)	$\top \sqsubseteq \forall\mathsf{needed\text{-}by}.\mathsf{Task}$	(19)
$Property(\mathsf{depends\text{-}on})$	(9)	$\exists\mathsf{qualifies}.\top \sqsubseteq \mathsf{Quality}$	(20)
$\mathsf{Goal} \sqsubseteq \mathsf{IntentionalElement}$	(10)	$\mathsf{refines\text{-}and} \sqsubseteq \mathsf{refines}$	(21)
$\mathsf{Quality} \sqsubseteq \mathsf{IntentionalElement}$	(11)	$\mathsf{refines\text{-}or} \sqsubseteq \mathsf{refines}$	(22)

Fig. 3. Description-logic vocabulary for i*, expressible in RDFS

Listing 1. RDF representation of political dimension of PESTEL analysis in Fig. 1

```
:Politics istar:wants :Regulate_Competition ,
  :Attract_Low-Fare_Airlines , :Minimize_Airport_Fees .
:National_Government istar:particpates-in :Politics .
:European_Commission rdf:type istar:Agent ;
  istar:particpates-in :Politics .
:Regulate_Competition rdf:type istar:Goal ;
  istar:depends-on :No_Monopolies.
:No_Monopolies rdf:type istar:Quality ;
  istar:depends-on :European_Commission .
:Attract_Low-Fare_Airlines rdf:type istar:Goal .
:Minimize_Airport_Fees rdf:type istar:Goal ;
  istar:depends-on :Discount_Airport_Fees ;
  istar:refines-or :Attract_Low-Fare_Airlines .
:Discount_Airport_Fees rdf:type istar:Task ;
  istar:depends-on :National_Government .
:Airline istar:wants :Cost_Control ,
  :Low_Operating_Costs .
:Low_Operating_Costs istar:qualifies :Cost_Control .
:Low-Fare_Airline istar:is-a :Airline ;
  istar:wants :Negotiate_Low_Fees ,
    :Low_Operating_Costs .
:Negotiate_Low_Fees rdf:type istar:Goal ;
  istar:depends-on :Fee_Discount ;
  istar:helps :Low_Operating_Costs .
:Fee_Discount istar:depends-on :Minimize_Airport_Fees .
:Ryanair istar:participates-in :Low-Fare_Airline ;
  istar:wants :Growth , :Rapid_Expansion ,
    :Mergers_and_Acquisitions , :Organic_Growth .
:Growth rdf:type istar:Goal .
:Rapid_Expansion istar:qualifies :Growth .
:Mergers_and_Acquisitions rdf:type istar:Goal ;
  istar:helps :Rapid_Expansion .
:Organic_Growth rdf:type :Quality ;
  istar:depends-on :Deny_Merger ;
  istar:hurts :Rapid_Expansion .
:Deny_Merger rdf:type istar:Task ;
  istar:depends-on :Regulate_Competition .
```

We can classify PESTEL factors as opportunities or threats using a SPARQL SELECT query (Listing 2) over the corresponding RDF representation. Each result tuple of the query classifies a factor as opportunity or threat for a particular actor. The classifications are expressed using the classes Opportunity and Threat (with a swot prefix). Hence, a PESTEL factor is classified an opportunity or threat for an actor if one of that actor's primary goals is qualified by a quality that is helped or hurt, respectively, by an intentional element that (transitively) depends on the

Listing 2. Generic SPARQL query to classify factors as opportunities or threats

```
SELECT DISTINCT ?actor ?factor ?classification WHERE {
 ?actor istar:related-with*/istar:wants ?goal .
 ?quality istar:qualifies ?goal .
 {
  ?actor istar:related-with*/istar:wants ?help .
  ?help istar:helps+ ?quality .
  ?help istar:depends-on+/istar:refines* ?factor .
  ?dimension istar:wants ?factor .
  BIND(swot:Opportunity AS ?classification)
 } UNION {
  ?actor istar:related-with*/istar:wants ?hurt .
  ?hurt istar:hurts+ ?quality .
  ?hurt istar:depends-on+/istar:refines* ?factor .
  ?dimension istar:wants ?factor .
  BIND(swot:Threat AS ?classification)
 }
}
```

PESTEL factor in question. Consider, for example, the RDF data set in Listing 1. The goals `Minimize_Airport_Fees` and `Attract_Low-Fare_Airlines` would be classified opportunities for low-fare airlines, the goal `Regulate_Competition` a threat for Ryanair[1]. `Regulate_Competition` becomes a threat for Ryanair via the dependency of `Organic_Growth` which hurts `Rapid_Expansion`, a qualifier of the primary goal `Growth`. Note that the SPARQL query in Listing 2 requires RDFS reasoning to be performed prior to query execution.

Other SPARQL queries, possibly in combination with external data sources, could also serve to formalize industry analysis using Porter's Five Forces. For example, in Fig. 2, the bargaining power of Ryanair's suppliers could be determined by counting the number of suppliers in a relationship with Ryanair. With a more comprehensive model, more complex graph analysis could also serve for computing the characteristics of Porter's Five Forces. Furthermore, using SPARQL's `SERVICE` clause, external data sources such as DBPedia[2] and wikidata[3] could be integrated into the analysis, e.g., to compute the bargaining power of suppliers and customers, or automatically determine potential suppliers, customers, and substitutes. In particular, these external sources could provide company facts such as revenue and number of employees. In that case, the resources in the analysis would have to be linked to the external data sources via OWL's sameAs property or similar.

[1] This threat is a reference to Ryanair's attempted takeover of Aer Lingus starting in 2007, which was eventually blocked by the EU Commission [9, p. 617ff.].

[2] http://wiki.dbpedia.org/.

[3] https://www.wikidata.org/.

4 Discussion and Future Work

Although intuition and creativity certainly are key drivers of successful strategizing [10], analytical and rational approaches to strategy-making are important complements for spontaneous action (see [5, p. 26] for more information on that discussion). In this sense, the formalization of strategy analysis using goal models and semantic web technologies must be regarded as complementary to the human element in strategizing, a form of knowledge management.

Future work will investigate the required organizational reengineering efforts as well as the associated technological aspects: Organizations must put in place a system to acquire, formalize and use strategic knowledge. Concerning knowledge elicitation, we assume that strategy reports are often already available in textual form, compiled by strategic managers; these written reports must then be (semi-automatically) translated into ontologies. Furthermore, future work will investigate alignment with common methodologies and frameworks in knowledge management, e.g., the CommonKADS methodology [16].

Strategic reports formalized using semantic web technologies may be organized in OLAP cubes with ontology-valued measures [17]. The dimensions of such a cube set the context for the knowledge, serialized in RDF format, codified in the measures. The measures focus on complex dependencies between entities rather than condensing complex data and knowledge into a single numeric indicator. The dimensions typically represent provenance information, e.g., the department that compiled the report, and meta-information such as the timespan covered by the strategy report or the employed modeling language. Analysts may choose and combine strategy reports using the dimensions. The combined knowledge can be further analyzed using dedicated query operators. An OLAP system with ontology-valued measures then becomes a valuable tool for managing a company's strategic knowledge. Otherwise, in the "as-is" scenario, strategic reports have to be stored in textual form, possibly in different layouts, and with different writing styles and text structures, thus hampering combination of the knowledge in the reports through analysts. Also, common analytical questions cannot be expressed unambiguously and in a reusable form as with SPARQL queries.

Since strategy analysts are typically not IT experts familiar with semantic web technologies, future work will develop graphical modeling tools with integrated support for data analysis. The graphical notation will be based on i*, possibly adapting the syntax rules to facilitate modeling for strategy analysis. Translation of the graphical model into RDFS allows for a SPARQL-based implementation of data analysis. The MetaEdit+ domain-specific modeling environment[4] may serve to implement a modeling tool. In order to evaluate the approach, future work will conduct usability studies with domain experts in strategic management. Furthermore, depending on the employed framework for strategy analysis, business model ontologies such as e^3value and REA (see [1]) may be more suitable to represent strategic analyses. Knowledge required for one analysis framework could also be derived from knowledge modeled in another framework.

[4] http://www.metacase.com/products.html.

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