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# The Balanced Scorecard Ontology: A Semantic Approach to Enhance Strategy Management

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***Abstract*—The Balanced Scorecard, developed in 1992 by Kaplan and Norton, has evolved into a communication and strategy execution system widely adopted by organizations across various industries. This article explores the use of an ontology to bridge the gap between strategy management and data within the Balanced Scorecard framework. The Balanced Scorecard Ontology is introduced to store, validate, and analyze knowledge, containing information about the Strategy Map and Quantification Frameworks, essential for evaluating the strategy execution. The proposed ontology is designed, developed, and evaluated using competency questions, and further validated by an online tool. Specifically, the proposed formalization of the Balanced Scorecard framework provides a semantic layer aimed at facilitating an effective Balanced Scorecard implementation, enabling accurate, traceable, and continuous monitoring and improvement of the strategy execution, based on a data-driven approach. The formalization of this knowledge through an ontology encompasses several advantages, such as improved interoperability and validation of the framework's elements, inference of new knowledge, and enhanced communication between different stakeholders. Additionally, managerial implications include ensuring alignment between the Balanced Scorecard and organizational goals, supporting compliance and governance efforts, improving communication and knowledge transfer, enhancing the strategic decision-making process, and facilitating the integration of data into the Balanced Scorecard.**

***Index Terms*—Balanced Scorecard, Ontology, Strategy, Strategy Map, Quantification Framework**

## I. Introduction

The Balanced Scorecard (BSC) was developed in 1992 by Robert S. Kaplan and David P. Norton as a performance management system to support problem-solving and decision-making [1]. Initially, the BSC divided measures into four perspectives: Financial, Customer, Internal Processes, and Learning & Growth. This complementary set of measures was presented to business users as "dials and indicators in an airplane cockpit," allowing for a comprehensive view of past results, current operational performance, and, at the same time, monitoring future drivers.

The BSC has evolved significantly since its creation in the early 1990s, with many organizations adopting and adapting it to fit their specific needs and objectives [2]–[4]. Today, the BSC is seen as a communication and strategy execution system [5], [6]. It has been shown to improve organizational performance, enhance strategic alignment, and facilitate communication and coordination across different departments and levels of an organization. The BSC has been successfully applied in many industries, including Higher Education [7], [8], Healthcare [9]–[11], and Tourism [12]. Recent research has also explored the potential of the BSC to promote sustainability and corporate social responsibility by incorporating environmental and social measures [13], [14].

Combining the BSC with other systems and tools can lead to a more effective implementation [5]. Supino, Barnabè, Giorgino, *et al.* [15] enhanced the application of a BSC by integrating System Dynamics to improve decision-making and help in strategy formulation and implementation. Tawse and Tabesh [6] state that "the BSC has the potential to improve organizational performance, but to realize that potential, it must be effectively implemented." The authors provide three recommendations: (1) The development of a strategy map to ensure that BSC elements are causally linked; (2) Ensure Top Management Team commitment and support; and (3) Improve key stakeholder engagement through participation and frequent communication. Knowledge formalization techniques, such as ontologies, can be used to represent and make knowledge machine-readable and support the decision-making process [16], [17]. By formalizing BSC knowledge, interoperability between systems and the BSC could be improved, BSC elements and their relationships can be validated, new knowledge can be inferred, and lastly, ontology semantics can be used to enhance communication and reduce misunderstandings.

By an effective implementation of a BSC we mean that the BSC must enable an accurate, traceable, and continuous monitoring and improvement of the strategy execution, based on a data-driven approach. Since the early 2000's, authors have defended the importance of a quantitative and financial calculus when validating the BSC's strategic assumptions or hypotheses modeled using the cause-and-effect relationships [18]. However, to our knowledge, the BSC model has not evolved conceptually to incorporate these 'technical' validations, remaining primarily a 'business'-oriented strategic management approach. Organizations already use different management systems to retrieve, store, and analyze data. The technical-side implementation of data-driven decision-making has evolved in the last decades. Business Intelligence (BI) and Analytics systems have been used for data-driven decision support since the 1990s [19], [20], and there are currently industry guidelines or best practices that can be used

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Fig. 1. Execution Premium Process. Retrieved from Khakbaz and Hajiheydari [24]

to implement these systems (e.g., Data Warehouse and BI Systems [21] or Data Mining [22]).

The Execution Premium Process (see Figure 1) was presented in Kaplan and Norton [4], outlining key steps for effectively implementing a BSC, clearly stating the use of BI to facilitate the data optimization phase (”Monitor and Learn” and ”Test and Adapt”). This article proposes a technological and data-driven approach that formalizes the BSC model, bridging the gap between strategy definition and data-driven decision-making through a comprehensive Business Intelligence implementation. Particularly, the proposed semantic layer aims to support the integration, alignment, and traceability between strategic models and the organizational information systems necessary for providing data to the BSC's performance indicators. In today's fast-paced business environment, organizations are often forced to continuously adapt to changes, which may lead to a misalignment between the planned and executed strategies. This reinforces the need and relevance of establishing traceability and monitoring capabilities between strategic models and organizational information systems [23].

To this end, this article presents an ontology to store and analyze knowledge related to the BSC. The Balanced Scorecard Ontology (BSO) is introduced, containing information about the BSC's Strategy Map and Quantification Frameworks used to evaluate the strategy execution. The ontology is validated and evaluated using competency questions and an online tool designed to identify pitfalls in ontology development. The remainder of the article is structured as follows: Section 2 presents background research concerning ontologies, strategic models, and balanced scorecards; Section 3 introduces other existing BSC ontologies; Section 4 formalizes the BSC framework for this research's scope; The design and development of the BSO is presented in Section 5, and the ontology is validated and evaluated in the following section (Section 6); Lastly, conclusion and future work is presented in Section 7.

## II. Background

This section describes the background concepts necessary for this research: balanced scorecards, strategic models, and ontologies.

### A. Balanced Scorecard

The Balanced Scorecard was first introduced by Robert S. Kaplan and David P. Norton in a 1992 Harvard Business Review article [1]. In this article, Kaplan and Norton argued that traditional financial measures did not provide a complete picture of an organization's performance. They proposed using a more balanced set of measures, including financial and non-financial metrics, to better reflect an organization's performance.

Over the years, the Balanced Scorecard has evolved from a performance measurement tool to a strategic management system. In 1996, Kaplan and Norton published another article [2] that emphasized the importance of using the Balanced Scorecard to align an organization's strategy with its performance measures and to drive continuous improvement. The authors further expanded on the strategic management aspects of the Balanced Scorecard. They introduced the concept of strategy maps, a visual representation of an organization's strategic objectives and the cause-and-effect relationships between them [25]. Strategy maps help organizations to better understand how their objectives are interconnected and how they can best allocate resources to achieve their goals. The authors argue that the BSC is ”agnostic to the formulation model used,” [3] meaning that any business strategy formulation may be executed and communicated utilizing the BSC and its elements.

The BSC should be cascaded to align all levels of the organization to its strategy. This means that the organizational or corporative level BSC is translated to lower tiers of the organization (such as departments, teams, or individuals), with objectives and indicators becoming more specific or detailed as the BSCs are cascaded down. This vertical alignment creates an outlook between the employees and the high-level strategy, clarifying how each strategy level contributes to achieve organizational success and how they help in realizing the organization's vision [4].

### B. Strategic Models

The definition of a Business Strategy is essential for any entity to achieve its goals and vision, guiding the decisions to obtain a competitive advantage against the competition. Porter's Five Forces, Blue Ocean Strategy, and the Business Model Canvas are some of the models that can be used to formulate a strategic approach, clarify the business model and help to define a BSC.

Porter states that the ”essence” of strategy formulation is to define how to adapt and stay competitive against your competition [26]. Porter presents five fundamental forces that

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can change an industry's competition state, from which companies must defend or influence to achieve long-run profitability. Possible entrants to the industry, the power of suppliers and buyers, the arrival of substitute products, and the existing competition within the industry must be analysed and monitored to ensure that the company's advantage is achieved and defended.

The Blue Ocean Strategy [27] looks for an unknown market space where competition is non-existing. To do so, it is necessary to create a new value curve, where we look to eliminate, reduce or raise some factors in an existing industry or create something new to the industry. This leads to cost reduction and added (or new) value for the customers, allowing the business to keep existing customers and attract new ones.

The Business Model Canvas (BMC) [28] simplifies the business concept, by clarifying the organization methods and functions and developing an agile strategy definition framework. The BMC design includes the identification of customer segments, value propositions, channels, customer relationships, revenue streams, key resources, key activities, key partnerships and cost structure as the main building blocks for the "rationale of how an organization creates, delivers, and captures value [29].

The customer value proposition defines how a company creates value for its customers to increase customer acquisition, satisfaction, and retention. Treacy and Wiersema [30] studied how various industry leaders achieved a dominant market position, and discovered that this could be achieved by increasing the focus on customer intimacy, operational excellence, or product leadership. They then proposed that a company should strive to stand out by performing exceptionally in one of the three proposals, while maintaining the industry's minimum threshold on the other two. This model was used by Kaplan and Norton [31] to structure the strategic objectives definition in the BSC customer perspective, in terms of three very different strategies: Best Total solution (customer intimacy), Best Buy (operational excellence), and Best Product (product leadership).

Osterwalder, Pigneur, Bernarda, *et al.* [32] proposed another value proposition model, aligned with the BMC [28], called the Value Proposition Canvas (VPC). This model helps a company to design a product or service aligned with the customers' wants and needs. Given the Customer Profile (defined in terms of the the jobs customers are trying to get done, the gains they expect to achieve, and the negative impacts (or pains) they might suffer), the goal is to define an aligned Value Map. This component defines the main characteristics of the product/service offered to help the customer to complete its jobs, demonstrating how the company intends to create the expected gains, and relieve the pains. This value proposition model is not referenced in Kaplan and Norton's work. However, we have been using it for almost ten years in university-level business and information systems classes to design BSC, as shown in works such as Silva [33], Cardoso, Santos, Costa, *et al.* [34], and Sacoor, Arsenio, Cardoso, *et al.* [35]. We have found that the VPC enables a richer strategy definition for the customer perspective. Moreover, Treacy and Wiersema [30] focused on industry leaders, while the VPC can be applied to any company, even a startup, and to a strategy that does not aim simply to gain a dominant market position.

### C. Ontologies

Ontologies are "formal, explicit specifications of shared conceptualizations" [16]. They are used to describe knowledge about a certain domain of interest, its concepts, properties, and relationships. Ontologies are used to share, reuse and analyze knowledge, facilitating interoperability and heterogeneity [36], which is why they are an integral part of the Semantic Web[1]. Knowledge Base refers to an ontology populated with individual instances [37].

Resource Description Framework (RDF) is a World Wide Web Consortium (W3C) recommendation to "create, exchange and use annotations on the Web". The resources are described in the form of triples (*subject property object*) [38]. RDF Schema (RDFS) provides a vocabulary for RDF, introducing class and hierarchy concepts. The Ontology Web Language (OWL) was developed on top of RDFS, adding disjointness, cardinality, object and data properties, and other additional vocabulary and expressiveness. There are three OWL sub-languages/types: Lite, DL, and Full, with different levels of expressiveness. The choice of a language depends on the problem domain and modeling requirements, with an identified trade-off between expressiveness and inference capabilities (reasoning) [39].

## III. Balanced Scorecard Ontologies

A set of works was retrieved from the Web Of Science Core Collection[2] using the search query: **"Balanced Scorecard" (All Fields) AND (Ontology OR Ontologies OR "Semantic Web" OR "Knowledge Base" OR "Knowledge Representation" OR "Ontological Model") (All Fields)**. The filter Languages = (English) was the only additional filter used. The results were added to VosViewer[3] where an analysis of keywords co-occurrence was performed on the bibliographic data (see Figure 2). Note the importance of benchmarking, agency and ontology, and the connection between the strategy, performance, and the Balanced Scorecard.

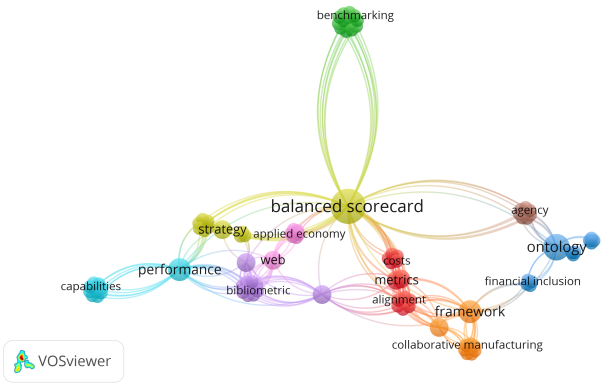


Fig. 2. VosViewer Network Visualization for BSC Ontologies Research

[1]https://www.w3.org/standards/semanticweb/
[2]www.webofscience.com
[3]https://www.vosviewer.com/

TABLE I
BSC ONTOLOGIES

| Work | Ontology | Objective | Linked Ontologies |
|---|---|---|---|
| Hartanto, Sarno, and Ariyani [40] | Warning Criterion Ontology (WCO) | "Detect the wrong pattern and wrong resource in the organization" | BSCO, WCO-Master, Petri net |
| Bobillo, Delgado, Gómez-Romero, *et al.* [41] | Fuzzy Balanced ScoreCard Ontology (fBSCO) | Integrate fuzzy logic with BSC methodology | FKRO |
| Navarro-Hernandez, Perez-Soltero, Sanchez-Schmitz, *et al.* [42] | Balanced Scorecard Ontology (BSCO) | Link BSC to Business Models | eBMO[43] |

The 18 publications were published between 2002 and 2022, from which full text concerning three works were unavailable. From the 15 available works, only three presented original ontologies related to the BSC framework. Tables I and II present a summary of the ontologies found in these publications, analyzing which BSC elements were mapped into the ontology, the primary objective presented for the ontology development and information about other ontologies used (linked ontologies).

The Balanced Scorecard Ontology (BSCO) [42] was developed to "achieve a conceptualization of the business processes, aligned to the strategy of the organization, to be captured, represented, disseminated and processed by the people and software systems". The ontology allows the definition of Objectives, Initiatives, Perspectives and Measures (see Figure 3). No information is given regarding relationships between these entities.

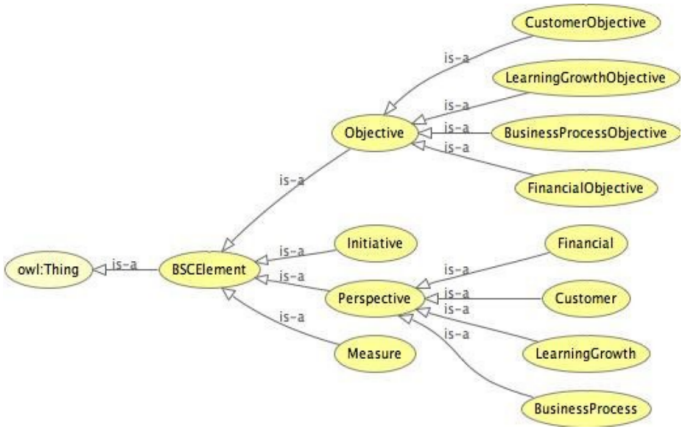


Fig. 3. Balanced Scorecard Ontology (BSCO). Retrieved from Navarro-Hernandez, Perez-Soltero, Sanchez-Schmitz, *et al.* [42]

Warning Criterion Ontology (WCO) [40] represents some BSC concepts, such as Cascading (on organizational units and employees) and defines relationships to some BSCO entities (e.g., Activities to BSCO indicators). Lastly, the Fuzzy Balanced Scorecard (fBSC) ontology [41] utilizes fuzzy logic to deal with uncertainty in BSC variables. However, the ontology is focused on Perspectives and indicators (Variables), with no information regarding the remainder of BSC elements.

None of the ontologies found during the literature review were able to represent all, or most, of the identified BSC elements, and available online. Therefore, a new ontological model can be developed to achieve the goals of this work.

TABLE II
BSC ONTOLOGIES ELEMENTS
(✓: FULLY MAPPED, **P**: PARTIALLY MAPPED AND **-**: THERE'S NO INFORMATION ABOUT THE MAPPING OF THIS ELEMENT)

| Ontology | Mission, Vision, Values | Perspectives | Strategic Objectives | Strategic Theme | Strategy Map | Performance Indicators | Targets | Initiatives | Cascading |
|---|---|---|---|---|---|---|---|---|---|
| WCO | - | p | - | - | - | p | p | - | ✓ |
| fBSCO | - | ✓ | ✓ | - | - | p | - | - | - |
| BSCO | - | ✓ | ✓ | - | - | p | - | ✓ | - |

## IV. FORMALIZING THE BALANCED SCORECARD FRAMEWORK

Over the years, Kaplan & Norton have refined an adaptable tool that enables executives and managers to tailor and employ their BSC with the detail needed to define their strategy [1]–[4], [25]. According to Speckbacher, Bischof, and Pfeiffer [44], Niven [45], and Lawrie and Cobbold [46], a first-generation or type I BSC only needs to contain financial and non-financial indicators grouped by the four perspectives to support strategic performance management (see Table III). Authors also concur that in order to advance a type I BSC to a type II BSC, it is necessary to define a strategy map. However, various approaches are found in the literature for achieving a Type III BSC. Cardoso [47] expands on the definition of Speckbacher, Bischof, and Pfeiffer [44] and states that a Type III BSC involves the integration the different management systems already in use by the organization. This type of BSC requires the use of Business Intelligence techniques, providing analytical capabilities to monitor the strategy execution. Following this definition, and for this work's scope, a Type III BSC is defined as a system for communicating and implementing the strategy that is fully integrated with all other systems.

At the end of the last century, the original authors of the BSC recommended the use of cause-effect relationships, which is necessary to achieve a type II or second generation BSC. Nevertheless, recent studies, such as Cokins, Pohlen, and Klammer [48] and Tawse and Tabesh [6], still feel the need to recommend using a strategy map (a BSC component that displays these relationships) to implement a BSC effectively. To formalize a BSC, it must be clear what components and elements are needed to maximize the benefits of the BSC framework as a strategic management system. This section

TABLE III
BALANCED SCORECARD TYPES

| Work | Speckbacher, Bischof, and Pfeiffer [44] | Niven [45] | Lawrie and Cobbold [46] |
|---|---|---|---|
| 1st Generation / Type I | "A specific multidimensional framework for strategic performance management that combines financial and non-financial strategic indicators" | "Utilized almost exclusively to capture and analyze financial and non-financial measures across the four perspectives." | Combination of an integrated set of performance indicators and measures (financial and non-financial), grouped into four perspectives. Focused on performance evaluation. |
| 2nd Generation / Type II | "A Type I BSC that additionally describes strategy by using cause-and-effect relationships" | Addition of strategic objectives to provide a context for selecting measures, resulting in the development of strategy maps. Furthermore, this generation introduced cause-and-effect modeling. | Identification of key business factors (key performance indicators) and their causal interrelations, materialized in the Strategy Map. Focused on performance management. |
| 3rd Generation / Type III | "A Type II BSC that also implements strategy by defining objectives, action plans, results and connecting incentives with BSC" | The BSC requires a destination statement, with a quantitative detail, of what the future aspect of the organization should lool like at a certain date | Focused on Strategic Alignment and Change Management Support |

defines the framework elements used in this work and how they relate, based on the work developed in Cardoso [47].

Two major components are needed to define a BSC at any strategic level: a Strategy Map and a Quantification framework (see Figure 4). A Strategy Map presents the long-term view of the strategy: the strategy statement, the main objectives, and how they are organized, while the Quantification Framework offers a shorter-term view containing the tangible indicators, goals, and initiatives needed to translate the strategy into operational terms.

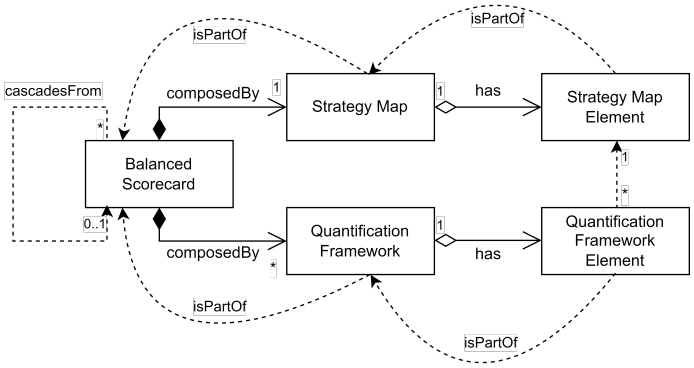


Fig. 4. Balanced Scorecard Components

### A. Strategy Map

In a BSC, the Strategy Map provides a visual representation of the long-term strategy, which is a value-creation roadmap. This component contains the set of strategic objectives and displays the cause-effect relationships needed to clarify how each strategic objective contributes to the execution of the strategy. Other elements present in a strategy map are perspectives, strategic themes (which group objectives in a set of cause-and-effect relationships, coherently showing how to achieve the strategic theme) that can be used to decompose the vision statement. This vertical use of strategic themes is aligned with the most recent contribution of Kaplan and Norton regarding this topic Kaplan and Norton [3], [4]. The main elements of the Strategy Map are presented in Table IV-A, and their primary relationships are shown in Figure 5.

As a long-term strategy tool, strategy statement elements, such as vision, mission, and values, should also be considered part of the strategy map (although not always part of the visual representation). While an organization's Mission typically remains unchanged over time, the Vision statement is normally a three to five-year concise, inspiring, and realistic (medium/long-term) goal. The BSC is intended to serve as a roadmap, guiding organizational endeavors towards attaining this desired position within the specified timeframe and niche. The Vision should include a well-defined stretch goal, establishing the performance indicator and a target value to assess the success of the vision's realization.

TABLE IV
STRATEGY MAP ELEMENTS DESCRIPTION

| **Element** | **Element Description** |
|---|---|
| Perspective | Perspectives divide the BSC into different views. The standard perspectives are Financial, Customer, Internal Process, and Learning & Growth. |
| Strategic Objectives | Strategic objectives are used to break down strategy into actionable steps, operationalizing the strategy. They should be concise and quantifiable, mapping how the organization can achieve its Vision; |
| Strategic Themes | Major strategic forces or high-level areas of action, covering the different perspectives. The Vision is usually decomposed to obtain these themes; |
| Mission | The mission statement defines the purpose of an organization, i.e., the reason for its existence; |
| Vision | A concise, inspiring, visionary and realistic objective statement for the medium/long term goals. All organizational efforts should be made to achieve this desired position. A Vision must have a time period, a stretch goal, and a niche (aligned with the latest recommendation by Kaplan and Norton [4]); |
| Values | Organizational values define the guiding principles for the day-to-day employee behaviour, decisions and interactions; |
| Stretch Goal | Defines the target value related to a performance indicator with a clear timeframe to achieve it, enabling a clear quantification of the vision statement. |

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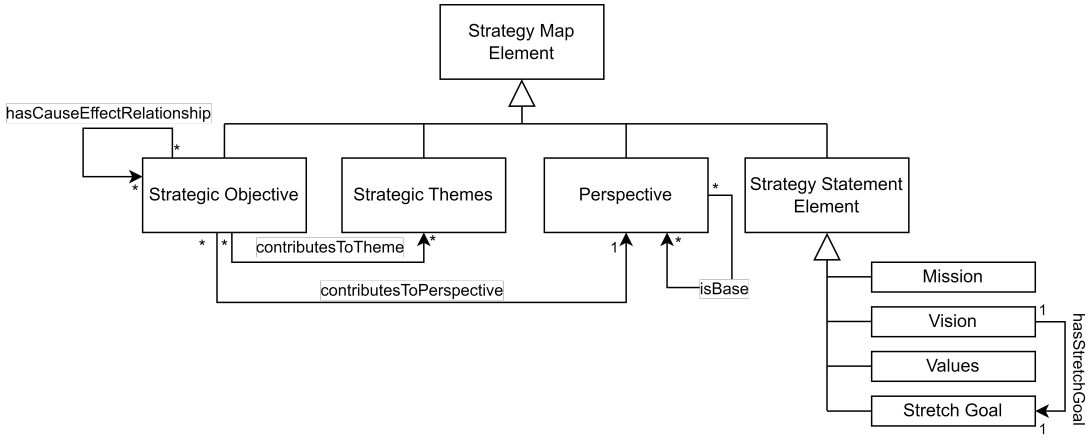


Fig. 5. Strategy Map Elements and their main relationships

### B. Quantification Framework

A Quantification Framework provides a short-term view of the strategy execution and concerns a defined time interval, usually a year, meaning that a set of Quantification Frameworks is expected to be defined for a strategy map in a BSC project. The main elements of this component are presented in Table V and their primary relationships are shown in Figure 6.

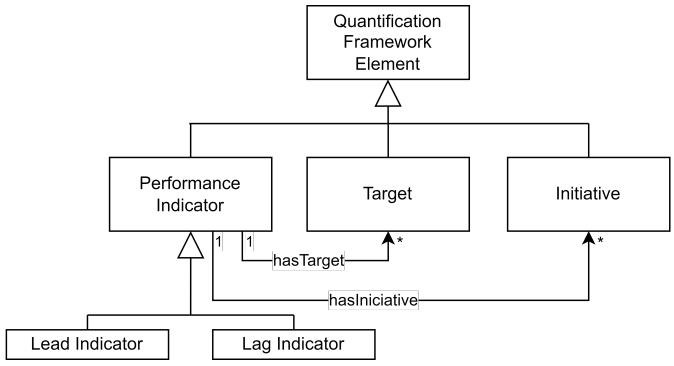


Fig. 6. Quantification Framework Elements and their main relationships

The central element of a Quantification Framework is the Performance Indicator. Performance indicators are used to monitor and evaluate a specific strategic objective and can be divided into Lead (drivers, enablers, predictive) or Lag (results) indicators. The relationship between objectives and indicators (see Figure 7) ensures the connection between a strategy map and its quantification frameworks inside a BSC. Each performance indicator must have a set of associated metadata attributes, for example: a frequency (e.g., quarterly), polarity, unit type (e.g., percentage), calculation formula, and other information related to the data origin (source, quality, collector). These attributes are generally associated with performance indicators templates [45], describing mandatory and optional attributes.

Each Performance Indicator should have a well-defined Target, indicating the desired future state to be achieved within a specific time interval. Additionally, a set of Initiatives must be identified to provide actionable plans directly impacting these indicators.

TABLE V
QUANTIFICATION FRAMEWORK ELEMENTS

| Element | Element Description |
|---|---|
| Performance Indicators (KPIs) | Performance indicators are used to monitor and evaluate the strategic objectives' state or fulfillment. Key Performance Indicators (KPI) are highly aggregated metrics that assess critical organizational aspects. Performance Indicators can be divided into lead (enablers or predictive) and lag (results); |
| Targets | Targets establish objective goals for each indicator, by defining a "value and time" pair. These targets identify value gaps between the current reality of an organization and its desired future state; |
| Strategic Initiatives | Strategic initiatives are projects with a defined priority that have a direct impact on a set of indicators; |

### C. Cascading the BSC

Balanced Scorecards should be defined throughout the organizational levels, allowing the managers to define strategy at the corporate, department, team, or even at the individual level. Information needs are distinct, as is the level of detail (or summarization) of performance indicators and data.

As noted, a corporate or enterprise-level BSC should consist of a well-defined Strategy Map and Quantification Frameworks to effectively execute its strategy. However, the strategic elements within an corporate-level BSC, such as strategic objectives and performance indicators, are likely impacted by the corresponding elements at lower levels of detail, which should be defined by BSCs at lower hierarchical levels. Conceptually, a BSC is the sum of all the BSCs defined at different organizational levels, from the corporate level (if this is the highest level at which it has been defined) to the lowest level of cascading.

Regarding the BSC elements, two types of cascading have been identified (see Figure 8). An element within the framework may be the same as another element at a lower level of

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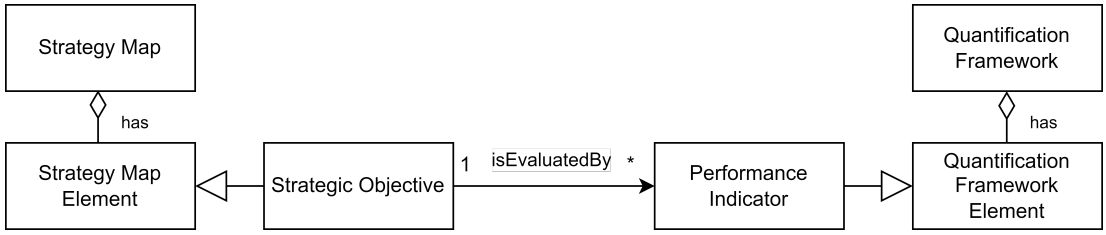


Fig. 7. Relationship between Strategic Objective and Performance Indicator

detail (for example, a corporate indicator or objective with a specific filter/focus on a singular department, represented by the ”isDecompositionOf” relationship). Alternatively, it may be a distinct element but share a cause-effect relationship (such as an individual-set objective contributing to a department-level objective, represented by the ”hasCauseEffectRelationship” relationship).

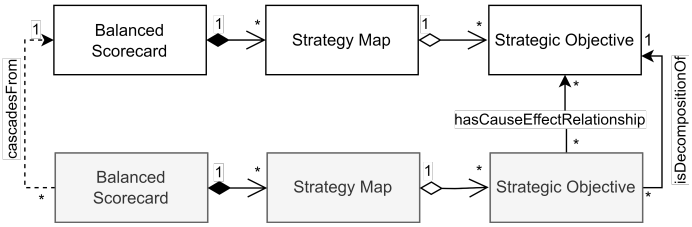


Fig. 8. Cascading at BSC and Strategic Objective level. The BSC represented in grey cascades from the white BSC.

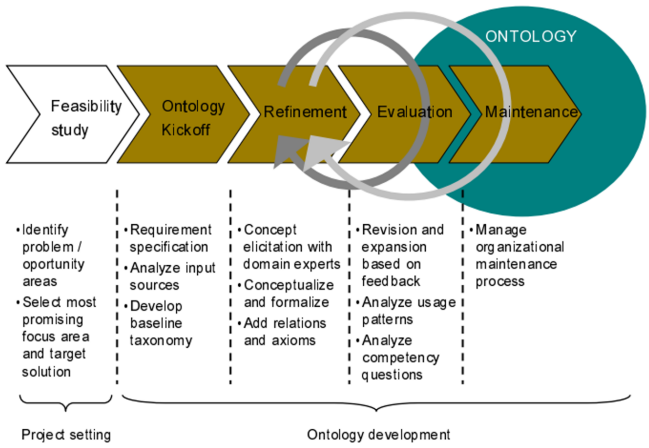


Fig. 9. On-to-Knowledge Methodology. Retrieved from Staab, Studer, Schnurr, *et al.* [49]

## V. Balanced Scorecard Ontology

This section presents the main contribution of this work, which is the development of the Balanced Scorecard Ontology (BSO). The On-to-Knowledge methodology [49] was utilized to outline the necessary activities for the ontology's development process. Below, the Ontology Requirements Specification Document is presented. Subsequently, the development process is discussed, highlighting the major decisions taken throughout the process.

### A. Ontology Requirements Specification Document

*1)* ***Domain and Scope****:* The BSO was developed to describe and store knowledge related to the Balanced Scorecard framework, following the formalization presented in Section IV, which divides the BSC into a long-term view (Strategy Map) and a shorter-term view focused on strategy execution (Quantification Framework). The ontology must be able to describe at least a Type II BSC (see Section II-A).

*2)* ***Goals****:* The ontology should represent, provide information and allow inference on BSC components, specifically the Strategy Map and Quantification Framework, the BSC elements, such as Strategy Statement elements (Vision, Mission, and Values), Strategic Objectives, Perspectives, Themes, and Performance Indicators, and the relationships between these elements (e.g., cause-effect between objectives).

*3)* ***Users, Use Cases and Applications****:* The BSO should allow any organization and manager to formalize, translate, communicate, align, and execute its strategy. The ontology should also allow for strategy validation (e.g., ensure every strategic objective has a performance indicator) and improve interoperability between performance management systems and strategy.

*4)* ***Knowledge Sources and Reusable Ontologies (Inputs)****:* The BSO was based on Kaplan & Norton's work [1]–[4], [25] and the formalization presented in Cardoso, Trigueiros, *et al.* [7]. Descriptions were based on Niven [45]

*5)* ***Competency Questions****:* Table VI presents the main competency questions (CQ) for which the ontology must provide answers. However, it is essential to recognize that this set of CQ is not exhaustive. These questions aid in defining the ontology's scope, identifying core concepts and relationships, and ensuring completeness within the representation of domain knowledge. While CQ are valuable guides for ontology development, they do not cover every possible scenario or nuance within a domain. In this case, CQ were defined to ensure that the ontology correctly represents a BSC, while some CQ, such as CQ8, were defined to exemplify the use of the BSO in new knowledge extraction and inference.

### B. Ontology Development

The ontology was developed following the specification presented in Section IV. Figure 10 presents BSO's class hierarchy,

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TABLE VI
COMPETENCY QUESTIONS

| | |
|---|---|
| **Balanced Scorecard** | |
| CQ1 | What are the strategy statements associated with a certain BSC? |
| CQ2 | What is the "time horizon" associated with a certain BSC? |
| CQ3 | What is the strategic level of a certain BSC? |
| **Strategy Map** | |
| CQ4 | How many objectives are part of a Strategy Map of a certain BSC? |
| CQ5 | Which Perspectives or Themes are used in a certain Strategy Map? |
| CQ6 | How are Perspectives related in a certain Strategy Map? |
| **Strategic Objectives** | |
| CQ7 | What are the Perspective and Themes of a certain Strategic Objective? |
| CQ8 | Which objectives are directly or indirectly impacted by a certain Strategic Objective? |
| CQ9 | Which Performance Indicators are used to evaluate a certain Strategic Objective? |
| **Performance Indicators** | |
| CQ10 | Is a certain indicator a lag or lead indicator? |
| CQ11 | What is the Unit type/Frequency/Polarity of a certain indicator? |
| CQ12 | What is the Formula/Data Source/Data Quality of a certain indicator? |
| CQ13 | Which targets are defined for a certain indicator? |
| **Strategy Execution** | |
| CQ14 | Which initiatives are planned, and which performance indicators do they impact? |
| CQ15 | What is the latest value for a certain performance indicator? And which is the next target? |
| **Cascading** | |
| CQ16 | How is a certain BSC cascaded? |
| CQ17 | Which are the Strategic Objectives within the cascaded Balanced Scorecards that impact a certain objective, either through decomposition or cause-effect relationships? |

including the Balanced Scorecard, its Components, and its Elements. Each class is annotated using a label (rdf:label) and/or a description (dc:description[4]).

Object and data relationships were also created. From a structural point of view, the Balanced Scorecard is composed by a set of Components ("**hasComponent**") which in turn have a set of BSC Elements ("**hasElement**"). The Strategy Statement Elements are related to each BSC using the relationships "**hasMission**", "**hasVision**" and "**hasValue**". The Vision class is defined as Strategy Statement Element with a defined deadline (represented as a xsd:dateTime[5] using the data property "**hasTimeFrameEnd**") and a Stretch Goal. This Stretch Goal is related to a Performance Indicator and must have a defined target (stated using the data property "**hasValue**"). The Balanced Scorecard must also have a strategic level ("hasStrategicLevel").

The focal point of a Strategy Map are Strategic Objectives and their contributions to other elements in the Strategy Maps, namely the Perspectives, Strategic Themes, and other Strategic Objectives. To formalize these relationships, the

[4]dc: Dublin Core Metadata - https://www.dublincore.org/
[5]xsd: XML Schema Definitions

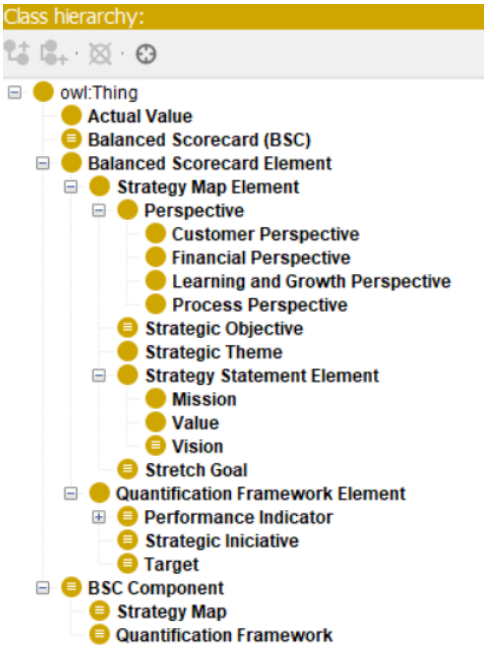


Fig. 10. BSO Class Hierarchy

following object properties were created as a sub-property of "**contributesTo**":

1) **contributesToPerspective** - Direct contribution from a Strategic Objective to a Perspective (functional);
2) **contributesToTheme** - Direct contribution from a Strategic Objective to a Strategic Theme;
3) **hasCauseEffectRelationship** - Direct contribution from a Strategic Objective to a Strategic Objective in a Strategy Map;
4) **isDecompositionOf** - Contribution from a Strategic Objective to another in a higher level of detail.

Each Strategic Objective is evaluated by a set of Performance Indicators, which is formalized using the relationship "**isEvaluatedBy**". Each indicator can be characterized by a group of data properties related to data sources, quality, and formula, as well as indicator frequency, polarity, and unit type (e.g., percentage), among others. Using the "hasTarget" and "hasIniciative", a Performance Indicator can be related to a Target or a Strategic Initiative, respectively. A Target must have a defined deadline. Lastly, an Actual Value related to the execution of a Performance Indicator is formalized using the "hasActualValue" relationship. The Actual Value must have a certain value (using the data property "hasValue") related to a certain time window ("hasTimeFrame").

## VI. EVALUATION AND VALIDATION

This section presents the ontology evaluation process. Following the proposed methodology, the BSO is analyzed regarding the defined competency question. To achieve this, the ontology was previously populated, which is described below. Common pitfall detection is also realized using a well-known online tool.

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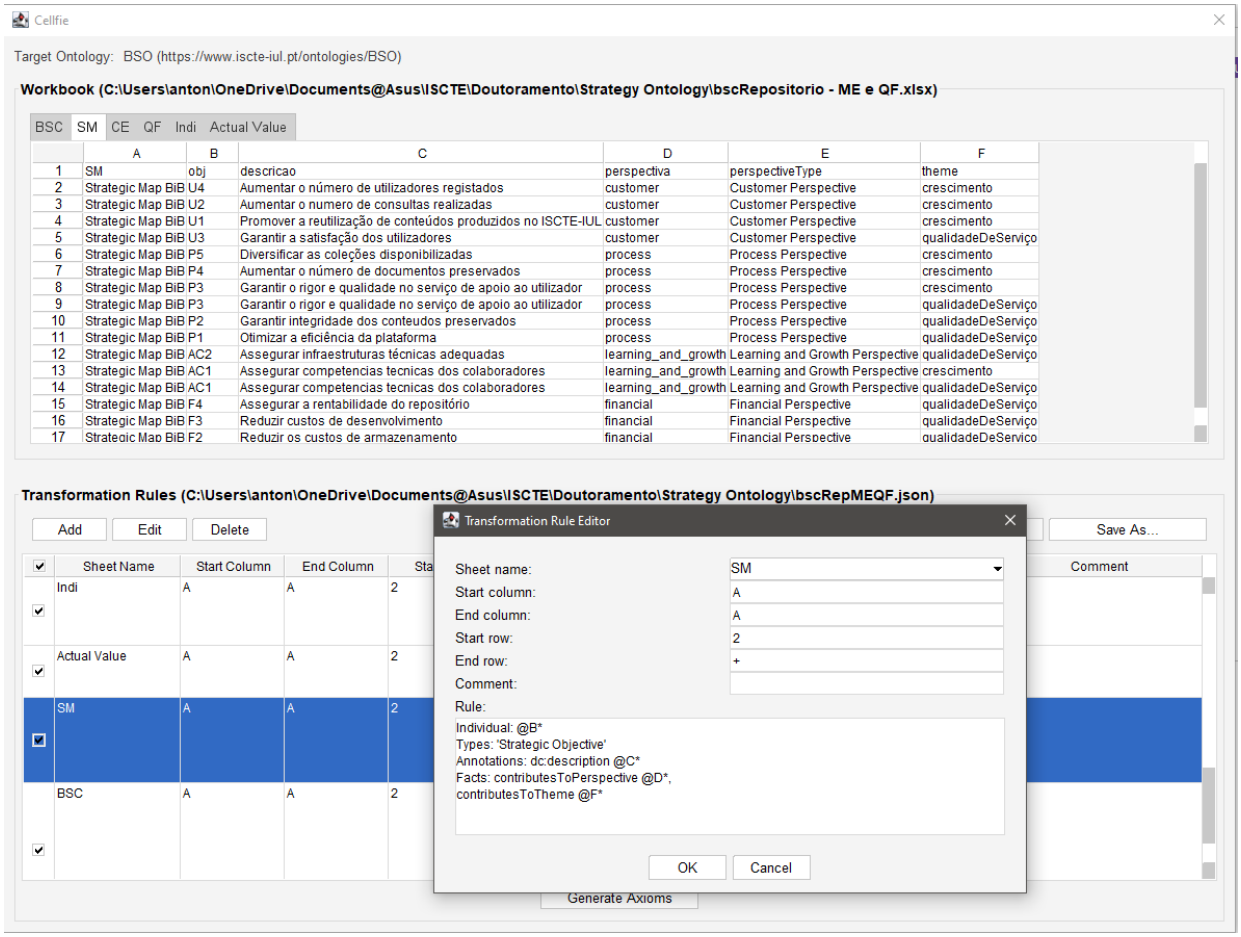


Fig. 11. Cellfie Rule Example

### A. Ontology Population and Case Study

Instance data was added to validate and evaluate the Balanced Scorecard Ontology. The process of adding instances to the ontology (A-box statements) is called ontology population, which was accomplished using a Protégé plugin called Cellfie[6]. Cellfie was used to define a set of import rules and mappings (based on Manchester OWL Syntax[7]) from Excel spreadsheets into OWL axioms (see Figure 11).

Strategy information was based on a public scorecard from a library repository of a higher education faculty [33]. Information related to Strategic Objectives, the cause-and-effect relationships between them, themes, and perspectives were available, as shown in A. Missing information was later supplemented, mainly information concerning indicators and execution values. In the end, instance information is available for querying inside the Protégé tool.

### B. Ontology Evaluation: Competency Questions

In this section, the BSO will be used to answer the Competency Questions defined in the Ontology Requirements Specifications Document (see Section V-A). Due to space limitations, the following CQ were selected to demonstrate the ontology:

TABLE VII
COMPETENCY QUESTIONS

| | |
|---|---|
| CQ1 | What are the strategy statements associated with a certain BSC? |
| CQ2 | What is the ”time horizon” associated with a certain BSC? |
| CQ5 | Which Perspectives or Themes are used in a certain Strategy Map? |
| CQ8 | Which objectives are directly or indirectly impacted by a certain Strategic Objective? |
| CQ13 | Which targets are defined for a certain indicator? |
| CQ15 | What is the latest value for a certain performance indicator? And which is the next target? |
| CQ17 | Which are the Strategic Objectives within the cascaded Balanced Scorecards that impact a certain objective, either through decomposition or cause-effect relationships? |

As stated before, a Balanced Scorecard is defined as a strategy management system to help companies to achieve a desired future state. To define this state, organizations state their mission, a vision (the desired future state) and values that will guide the organization for the following years, which are formalized in the BSO using sub-properties from the ”hasStrategyStatementElement” object property. Competency questions CQ1 and CQ2 were defined to illustrate how the ontology can currently answer these questions. The SPARQL query for CQ1

[6]https://github.com/protegeproject/cellfie-plugin
[7]https://www.w3.org/TR/owl2-manchester-syntax/

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Listing 1
CQ1 - WHAT ARE THE STRATEGY STATEMENTS ASSOCIATED WITH A CERTAIN BSC?

```
SELECT ?Element ?Statement WHERE {
    <Balanced_Scorecard> bso:hasStrategyStatementElement ?Element.
    ?Element bso:hasValue ?Statement}
```

Listing 2
CQ2 - WHAT IS THE "TIME HORIZON" ASSOCIATED WITH A CERTAIN BSC?

```
SELECT ?Vision ?timeFrame WHERE {
    <Balanced_Scorecard> bso:hasVision ?Vision.
    ?Vision bso:hasTimeFrame ?timeFrame}
```

Listing 3
CQ8 - WHICH OBJECTIVES ARE DIRECTLY OR INDIRECTLY IMPACTED BY A CERTAIN STRATEGIC OBJECTIVE?

```
SELECT ?contributesTo WHERE {
    <Strategic_Objective> bso:hasCauseEffectRelationship+ ?contributesTo}
```

is shown in Listing 1, while CQ2 is shown in Listing 2 which returns the date (xsd:dateTime) associated with the defined Vision of a certain BSC. The notation of a class name between angle brackets (<>), e.g., $< Balanced\_Scorecard >$ is used to define any instance of that class.

Competency Questions from CQ4 to CQ8 are related to the Strategy Map and its elements. The query presented in Figure 12 returns the number of strategic objectives from the Strategy Map of a certain BSC grouped by its Perspectives (the query can be adapted for Strategic Themes instead of Perspectives). The query results are also presented. The "hasCauseEffectRelationship" property is used to analyse the impact between Strategic Objectives, as showed in Listing 3. In SPARQL, the plus sign in front of a property evaluates the property as if it is transitive, meaning that, despite only the direct relationships between the objectives being asserted, the query can infer over this relationship to analyze the indirect impact between them.

Snap SPARQL Query:

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX bso: <https://www.iscte-iul.pt/ontologies/BSO#>

SELECT ?Perspective (COUNT(?Element) AS ?NumberOfStrategicObjectives) WHERE {
   bso:StrategicMapBiB bso:hasElement ?Perspective.
   ?Perspective rdf:type bso:Strategic_Perspective;
            bso:hasContributionFrom ?Element.
   ?Element rdf:type bso:Strategic_Objective.
} GROUP BY ?Perspective
```

Execute

| ?Perspective | ?NumberOfStrategicObjectives |
|---|---|
| bso:learning_and_growth | 2 |
| bso:process | 5 |
| bso:customer | 4 |
| bso:financial | 4 |

Fig. 12. SPARQL query and results from CQ5 - Which Perspectives or Themes are used in a certain Strategy Map?

In order to evaluate the execution of the strategy, the ontology must provide information about the performance indicators that allow to evaluate each of the strategic objectives. The relationship between an objective and indicators is materialized through the object relation "isEvaluatedBy", which serves as a "link" between the Strategy Map and the Evaluation Framework. Thus, to answer questions such as the one on CQ9, it is enough to select the URI (Uniform Resource Identifier) of the objective and observe the range of this property (e.g., $< BSO : U1 >$ :isEvaluatedBy ?PerformanceIndicator"). Information concerning each indicator can be obtained through the data property "hasIndicatorInformation", which has sub-properties on unit type ("hasUnitType"), frequency ("hasFrequency"), data source ("hasDataSource") and data quality ("hasDataQuality"), among others (CQ10/11). Targets and initiatives are related to the indicators through the object relations "isTargetFor" and "hasImpactOn", respectively.

Furthermore, the ontology should store and evaluate information regarding the actual values collected for each indicator. These values should be captured through the information systems of each organization. To store these values, the "Actual Value" class was created, which encompasses the value and the time frame to which it refers. This data enables the ontology to answer questions such as CQ15 (Listing 5), which allows for assessing the success of the defined targets by comparing the latest value of an indicator with their target values and respective deadlines.

Finally, one of the key benefits enabled by utilizing the BSO is the ability to validate alignment between BSCs. This can be achieved by either employing "isDecompositionOf" object property between Strategic Objectives, which is a sub-property of "isContribution", establishing a cause-effect relationship between Strategic Objectives in different Strategy Maps, or by defining the cascading at BSC level ("cascadesFrom"). By establishing this link, comprehensive alignment analysis between objectives, indicators, and other essential elements becomes feasible, as shown in Listing 6.

Listing 4
CQ13 - WHICH TARGETS ARE DEFINED FOR A CERTAIN INDICATOR?

```
SELECT ?Target ?Time ?Value WHERE {
    ?Target bso:isTargetFor <Performance_Indicator>;
       bso:hasTimeFrameEnd ?Time;
       bso:hasValue ?Value.}
```

Listing 5
CQ15 -WHAT IS THE LATEST VALUE FOR A CERTAIN PERFORMANCE INDICATOR? AND WHICH IS THE NEXT TARGET?

```
SELECT ?ac ?endDate ?value ?targetValue ?targetDate WHERE {
    <Performance_Indicator> bso:hasActualValue ?ac;
        bso:hasTarget ?target.
    ?target bso:hasValue ?targetValue;
        bso:hasTimeFrameEnd ?targetDate.
    ?ac bso:hasTimeFrameEnd ?endDate;
        bso:hasValue ?value.
    FILTER NOT EXISTS{
        <Performance_Indicator> bso:hasActualValue ?otherAC.
        ?otherAC bso:hasTimeFrameEnd ?date.
        FILTER (?date > ?endDate)}
    FILTER (?targetDate > ?endDate && NOT EXISTS{
        <Performance_Indicator> bso:hasTarget ?otherTarget.
        ?otherTarget bso:hasTimeFrameEnd ?date.
        FILTER (?date < ?targetDate)})}
```

Listing 6
CQ17 - WHICH ARE THE STRATEGIC OBJECTIVES WITHIN THE CASCADED BALANCED SCORECARDS THAT IMPACT A CERTAIN OBJECTIVE

```
SELECT DISTINCT ?StrategicObjective WHERE {
    BIND (<StrategicObjective> AS ?targetObjective).
    {?StrategicObjective bso:isDecompositionOf ?targetObjective}
    UNION{
     ?StrategicObjective bso:hasCauseEffectRelationship ?targetObjective;
            bso:isPartOf ?lowerBSC.
     ?higherBSC bso:hasPart ?targetObjective;
            bso:cascadesTo ?lowerBSC.}}
```

### C. Ontology Validation

The ontology was validated using the OntOlogy Pitfall Scanner! (OOPS!) tool [50]. OOPS! detects common mistakes and pitfalls made during ontology development. When analysing the BSO, the tool did not detect any critical pitfalls, which "could affect the ontology consistency, reasoning, applicability, among others" [50, p.15]. Also, only one important pitfall was reported by the tool (P41: No license declared). OOPS! detected thirteen (13) minor pitfalls, however, these do not represent a problem or error.

The tool detected "Learning and Growth Perspective" as one case of "Merging different concepts in the same class", which is not applied since the this is a BSC perspective (and therefore a single element). Another minor pitfall detected related to the different naming convention used for the ontology elements (which followed a different pattern for Classes and relationships). Lastly, OOPS! found 11 cases of "inverse relationships not explicitly declared (e.g., "hasMission", "contributesToPerspective").

OOPS! tool also suggests that some properties, such as "hasCauseEffectRelationship" or "hasPart", could be either transitive or symmetric since they have the same domain and range. These suggestions were not followed due to the reasons below:

1) OWL reasoners cannot infer over complex properties, such as transitive plus asymmetric and irreflexive property[51], which could be the case of the "hasPart" property;
2) Most of these properties are used to define direct relationships between classes. While a cause-effect relationship could be seen as transitive, without a different property to model the direct and indirect contributions, the materialization of this transitivity would lead to a loss of knowledge;
3) This type of transitive analysis can still be obtained using SPARQL queries, as previously shown (see Listing 3).

## VII. DISCUSSION

This article introduces the BSO in an endeavor to bridge the gap between strategy management and data related to the BSC framework. The BSO provides a structured framework to store and analyze knowledge related to the BSC, incorporating

information about the Strategy Map and Quantification Frameworks used for evaluating strategy execution. Specifically, the suggested formalization of the BSC framework provides a semantic layer to facilitate the integration, alignment, and traceability of strategic models with organizational information systems, which are essential for supplying data to evaluate the BSC's performance indicators. As previously discussed, performance indicators measure the organizational progress in relation to the strategic goals, supporting decision-makers in the evaluation of the effectiveness of current strategies. In a comprehensive BI implementation, the BSO facilitates the data optimization phase (see Figure 1) enabling an effective BSC implementation, using a data-driven approach.

The BSO provides a formal, structured, and semantically rich representation of the BSC framework, ensuring consistency in how strategic objectives, performance indicators, and their relationships are defined and interpreted, and providing decision-makers with a shared and unambiguous understanding of the BSC components. This knowledge representation can capture the complex inter-dependencies and cause-and-effect relationships between various components, providing a deeper understanding of how they impact one another. Ontologies also support automated reasoning, enabling logical inferences that can help identify implicit relationships or conflicts within the proposed BSC model. For example, it can provide rules that enable the detection of wrongfully defined strategic objectives, alert when certain indicators are irrelevant to the organization's strategy (i.e., are not being used to evaluate any objective or long-term goal), or facilitate the analysis and validation of transitive cause-and-effect relationships. By adopting an ontology-based approach, this solution offers a flexible and semantically enriched environment for representing the complex relationships inherent to strategic management and data-driven decision-making. When compared to traditional BSC implementations, the BSO provides improved clarity and interoperability to an organizational strategy, necessary for improved strategic decision support throughout the organization.

### A. Contributions to the Literature

The present study contributes to the existing literature by addressing various identified gaps associated with the BSC implementation as a communication and strategy execution system. As shown in Table III, there is a consensus among authors concerning the definitions of first and second-generation BSCs. However, a shared definition for a Type III BSC was absent from the literature. Based on Cardoso [47] definition of a third-generation BSC, a comprehensive strategy communication and implementation system needs to integrate the BSC with the different systems already in use by the organizations. This integration is required to enable an accurate, traceable, and continuous monitoring and improvement of the strategy execution, based on a data-driven approach. Existing studies, such as those by Kumar, Prince, and Baker [5] and Tawse and Tabesh [6] also emphasize the importance of combining the BSC with other systems and tools for an effective implementation.

Moreover, recent studies [6], including ours, still find the need to recommend the use of strategy maps for an effective BSC implementation. The elements and relationships of this adaptable framework need to be formalized to ensure that the BSC implementation fully harnesses the benefits inherent to the BSC as a strategic management system. The formalization of knowledge through techniques such as ontologies offers several benefits [16], [17], including enhanced interoperability between systems, knowledge validation, inference of new knowledge, and the utilization of semantics to improve communication and minimize misunderstandings. However, none of the ontologies identified during our literature review could comprehensively or satisfactorily represent all BSC elements. Furthermore, none of these ontologies were available online.

Our work addresses these gaps by introducing and developing the Balanced Scorecard Ontology, which formalizes the BSC framework, explicitly defining its components, elements, and relationships. Additionally, this semantic layer facilitates the integration of the BSC implementation with other organizational information systems, due to the increased interoperability. The proposed BSO is an additional layer seamlessly integrated into the Business Intelligence part of the Execution Premium Process (as proposed by Kaplan and Norton [4]), enhancing the organizational strategic monitoring and improvement capabilities. This is a crucial contribution, given the growing importance of leveraging data in strategic decision-making processes in an evolving business environment [23].

### B. Managerial Implications

The utilization of the BSO presents several advantages for managers. Firstly, it helps to ensure alignment between the BSC and the organization's overarching goals. This formal representation enables managers to assess whether BSC elements contribute to the organization's strategy, thereby preventing the allocation of resources towards nonessential or superfluous indicators and objectives. Additionally, the ontology can aid in compliance and governance efforts by allowing managers to verify that the organizational strategy adheres to regulatory requirements and facilitates the documentation, reporting, and tracking of compliance with pertinent standards, such as European Commission policies and performance evaluation in public administration.

The BSO provides a clear and unambiguous representation of the BSC framework, ensuring that all stakeholders have a common understanding of the strategy, strategic objectives, and indicators. This can improve communication and alignment throughout the organization, across organizational levels, or between departments. Furthermore, the BSO can be a valuable tool for facilitating the transfer of knowledge within the organization. By formalizing the cascading impact of each BSC element, the contribution of individual or departmental objectives to the overall organizational strategy can be made clear. This clarity facilitates a better understanding of the strategic framework among employees and stakeholders, potentially serving as a motivational factor.

Moreover, the incorporation of the BSO in the strategic decision-making process can help safeguard that all decisions align with the organization's mission, vision, and strategic

objectives. This proactive approach helps to avoid decision-making that may not contribute to the long-term success of the organization. The ontology can enable scenario analysis, facilitating an understanding of how changes in specific indicators or objectives influence the overall strategy and making it easier to evaluate the potential consequences of different decisions. By encoding the relationships between strategic objectives, indicators, and other BSC elements, the BSO can help managers to understand the risks and benefits associated with each decision, make more informed choices, and adapt to changing circumstances.

The BSO can also facilitate the integration of data from various sources into the BSC model, streamlining the collection, analysis, and reporting of performance indicators, which can become key in supporting real-time or near-real-time monitoring of performance indicators and decision support. Finally, the ontology can be integrated with decision support systems (e.g., BI systems) to improve decision-makers' perspectives on organizational strategy and performance and empower managers with user-friendly information and tools to make informed, data-driven strategic decisions.

In summary, the BSO provides significant advantages for managers across large companies, SMEs, and startups by ensuring strategic alignment and efficient resource allocation, enhancing compliance management, and facilitating knowledge transfer and decision-making. In particular, the BSO helps streamline strategic data analyses, fostering efficient resource use and informed decision-making, and maintain regulatory compliance. Additionally, the BSO aids in establishing clear strategic direction, ensuring effective knowledge transfer and facilitating internal communication.

## VIII. Conclusions and Research Directions

This article presents the development and evaluation of the Balanced Scorecard Ontology (BSO). The BSO represents elements from the Balanced Scorecard framework and their relationships in a formal, comprehensible and explicit way. The Ontology Requirements Specification Document (ORSD, see Section V-A) is presented with information regarding the ontology a) goals, domain and scope, b) users, use cases and applications, c) knowledge inputs and d) competency questions. The main challenges found in the ontology design and development processes are described. The ontology was validated and evaluated by answering the competency questions defined in the ORSD, using a real-case study of a university library, and using the OOPS! tool. Through this process, it was proved that the BSO is able to formalize BSC knowledge, validate BSC elements and relationships, and infer new knowledge related to them.

With the design and development of the BSO concluded, future research directions include the introduction of rules that can validate ontological knowledge. Some validations are already in place. For example, the BSC class is defined as the equivalent of the class of things [(hasComponent some 'Quantification Framework') and (hasComponent exactly 1 'Strategy Map') and (hasStrategicLevel exactly 1 xsd:string)]. This will trigger an error on the ontology when a BSC has, for example, two "hasComponent" relationships to two Strategy Maps. However, due to the Open World Assumption used in OWL, if no "hasComponent" property is found to a Strategy Map, the ontology and the instances are still valid and no error is shown. Shapes Constraint Language (SHACL)[8] and Semantic Web Rule Language (SWRL)[9] can be used on top of RDF and OWL to constrain and validate ontological knowledge.

Furthermore, it is important to use the BSO in different applications and decision-support scenarios. The interoperability gained from the ontology could be used together with Enterprise Architecture (EA) models, such as ArchiMate, to ensure an alignment between strategy and other EA layers, such as business, application, and infrastructure. This alignment would ensure the integration between strategic business vision down to the IT infrastructure, allowing analysis between EA layers.

Lastly, and as stated before, analysis and evaluation of strategy execution should use real data managed by organizational information systems. However, the relationship between this data, i.e., the values collected for each indicator and the ontology representation of these values, is not trivial (different indicators, different detail levels, etc). Ideally, the values should be retrieved from information systems, such as BI systems, and loaded into the ontology using an automated or semi-automated process. This approach would enable an accurate and continuous evaluation of the strategy execution, leading to the realization of a Type III BSC, a comprehensive strategic management and execution system.

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## Appendix

The case study used in Section VI contains strategy information based on a public scorecard from a library repository of a higher education university developed and published in Silva [33]. Figure 13 presents the strategy map which includes:

- Four Perspectives: Financial, Learning & Growth, Internal Process, and Users. In public or non-profit organizations, the financial perspective is usually presented as the base of the strategy map;
- Two Strategic Themes: Quality of Service and Growth;
- Thirteen (13) Strategic Objectives, such as "Increase visibility" and "Increasing institutional reputation", from the Users perspective, and their cause-effect relationships;
- and, the Mission, on the top of the map.

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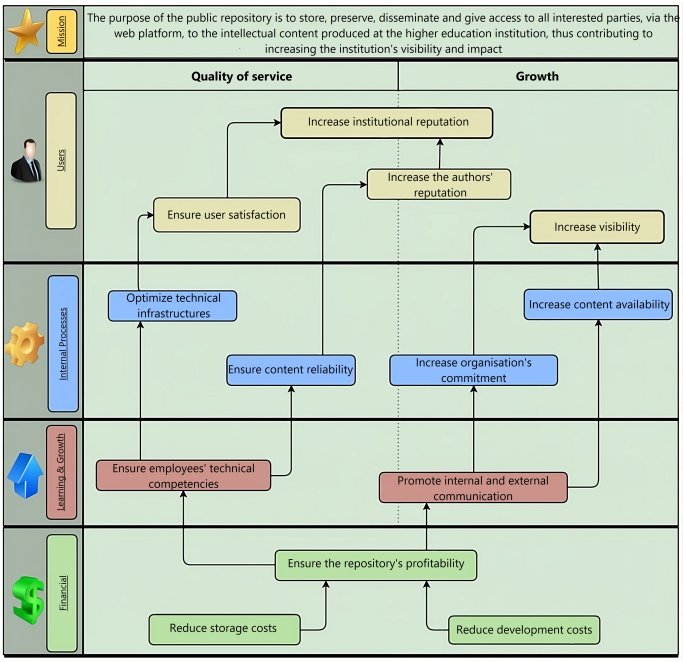


Fig. 13. Proposed strategy map for the library repository (translated from the original)


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