Conceptualizing and Specifying Key Performance Indicators in Business Strategy Models

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Abstract. Key Performance Indicators (KPI) measure the performance of an organization relative to its objectives. To monitor organizational performance relative to KPIs, such KPIs need to be manually implemented in the form of data warehouse queries, to be used in dashboards or scorecards. Moreover, dashboards include little if any information about business strategy and offer a scattered view of KPIs and what do they mean relative to business concerns. In this paper, we propose an integrated view of strategic business models and conceptual data warehouse models. The main benefit of our proposal is that it links strategic business models to the data through which objectives can be monitored and assessed. In our proposal, KPIs are defined in Structured English and are implemented in a semi-automatic way, allowing for quick modifications. This enables real-time monitoring and what-if analysis, thereby helping analysts compare expectations with reported results.

Keywords: Business Intelligence, Conceptual Data Warehouse models, KPI, SBVR, OLAP

1 Introduction

Key Performance Indicators (KPI) are used by organizations to monitor the performance of their processes and business strategies [10]. KPIs are traditionally defined with respect to a business strategy and objectives by using a Balanced Scorecard [7], to indicate what is to be monitored in different areas of the organization thereby providing a global view of the organization's status. These KPIs are then included in different dashboards, providing a detailed view of each specific area of an organization [3]. However, this approach entails that KPIs are (i) created in isolation, without describing inter-relationships between each other, and (ii) manually implemented by IT specialists. Unfortunately, this approach leads to several problems. First, it does not provide the decision maker with any information about the goal being monitored by a KPI and its effect on the rest of the business strategy. Second, even if a complex dashboard is developed, the decision maker is unable to validate if the KPI is correctly measuring its intended goal. Third, it is unable to verify that business strategy and the implemented KPIs are consistent with each other.

In order to address some of these issues, researchers have proposed to apply (semi-)formal techniques for strategy modeling. In [11] an i* profile for Data warehouses (DW) is used, focusing on building the underlying DW. On the other hand, the Business Intelligence Model (BIM) [1, 6] is proposed to support the analysis step, once the DW is already built. BIM allows us to model the business strategy including processes related to each goal, indicators, and potential situations which may affect goals, thus supporting SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis [5]. In this way, BIM provides a comprehensive view of the business strategy along with KPIs and their relationships.

In our previous work [9, 11], we defined a hybrid DW development approach in the context of the Model Driven Architecture (MDA) framework [12], in order to support the decision making process. In this paper, we complement our previous approach by proposing a semi-automatic process that obtains the value of each KPI, thus providing a comprehensive view of the organization's status. A summary of the process described throughout the paper is depicted in figure 1, and each step is further described on the corresponding section.

The remainder of this paper is structured as follows, Section 2 presents the basic concepts of BIM and introduces running examples for the rest of the paper. Section 3 describes how KPIs can be defined by using the Semantics of Business Vocabulary and Business Rules (SBVR) proposal [13]. Section 4 presents how to validate the KPIs defined against the DW schema. Section 5 describes how the proposed model can be used as a strategic dashboard which can also be navigated. Section 6 presents related work in this area. Finally, Section 7 summarizes conclusions and sketches future works.

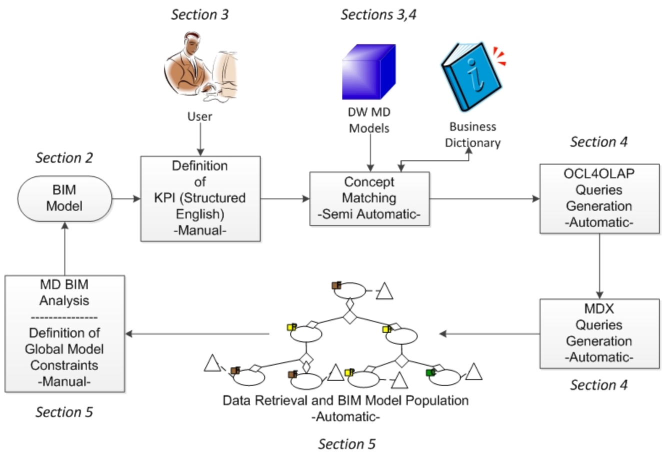

Fig. 1. Overview of the steps included in our approach

2 Basic Concepts and an Illustrating Example

In order to describe the basic concepts that underlie strategies and KPIs, which we will use throughout the paper, we present a running example, modeled after a fictitious vehicle manufacturer case study, the Steel Wheels company. The Steel Wheels company desires to improve its monitoring and decision making process. In order to improve this process, the company starts by modeling the business strategy, described textually in a business plan. The process of modeling the business strategy is performed by extracting four key types of elements from the business plan: goals, business processes, situations, and indicators, included in the BIM metamodel [6]. The definition of these key types is as follows:

Goals (a). Goals capture the objectives of the organization being modelled and depict a situation that an actor wishes to achieve [4, 11, 16]. For example, the main objective of Steel Wheels is achieving the "Revenue Increased" goal. In order to achieve it, the strategy can be decomposed into two alternative paths: "Costs Cut" and "Fancy Designs Created". As goals in BIM are related to their definition in the business plan, they also include their business perspective (Financial, Customer, Processes and Learning) from the Balanced Scorecard [7].

Processes (b). Business processes are responsible for the realization of the lowest level goals. In this way, "Innovative vehicle design" and "Design quality evaluation" processes realize the goal "Attractive vehicles designed", while "Sales zone planification" realizes the goal "Dealership distribution optimized".

Situations (c). Situations enable SWOT analysis over the business strategy and influence goals either positively or negatively depending on the relationship between them. For example, having "Positive Customer Reviews" is a strength (internal, positive) of the "Fancy Designs Created" strategy, which helps the goal "Customer satisfaction". On the other hand, the situation "Economic Crisis" is a threat (external, negative) for the business, and hurts the goal "Sales Increased".

KPIs (d). KPIs act as monitoring elements, measuring values related to goals or situations. Each indicator presents a target value (value to be achieved), a threshold (margin between good and bad performance), a current value and worst value. According to these values, the KPI is normalized in the range [-1,1], describing how good or how bad the measured element is performing.

By modeling these four types of elements, the Steel Wheels company BIM model is obtained. The result is depicted in figure 2. The Steel Wheels business strategy has one main goal: increase its revenue. In order to achieve this goal, two alternative ways to achieve this goal (courses of action) may be followed. On the one hand, the company can decrease the manufacturation costs of their vehicles, thus making them affordable for most customers but also lowering their quality. On the other hand, the currently chosen course of action, is to create high-quality designs, which are more expensive but also more attractive to customers. In turn, this course of action improves the image of the company, hopefully increasing its profit.

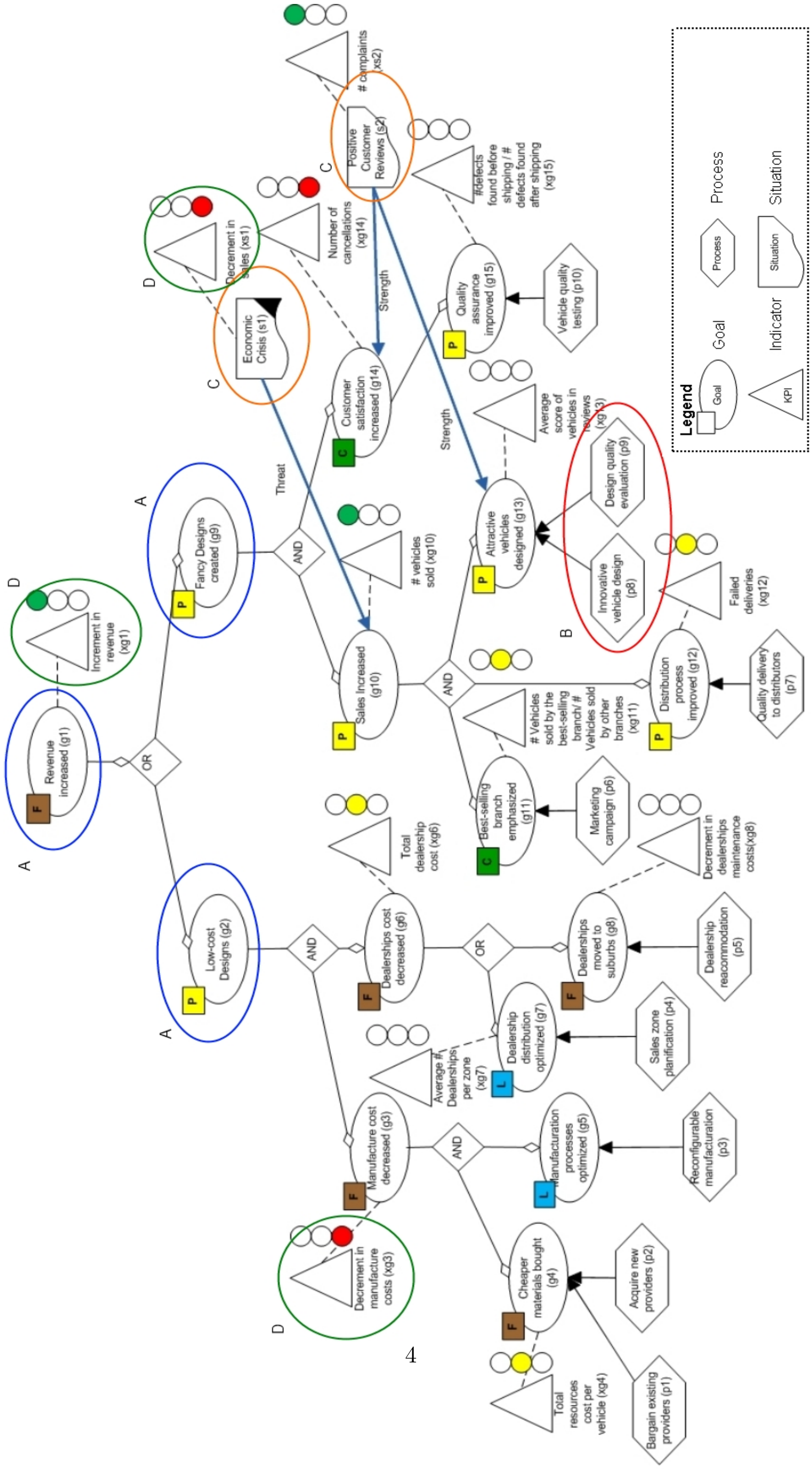

Fig. 2. Steel Wheels business strategy loaded with data

3 Definition of KPIs by using SBVR

After modeling the business strategy, we can identify the different elements involved in the business strategy, as well as the potential courses of action. However, so far this model only allows decision makers to plan and estimate the values of the different KPIs. Therefore, in order to gather feedback from business processes, we have to define how business KPIs are calculated.

We can consider two different kinds of KPIs which can be defined over the models, according to how they are calculated: atomic and composite. On the one hand, atomic KPIs are those whose value is obtained from the DW. For example, the KPI "Number of vehicles sold" which retrieves the total amount of vehicles sold from the Sales table would be an atomic KPI. On the other hand, the KPI "Increment in revenue" could be created as a composite KPI, obtaining its value from the difference of "Gross profit" minus "Manufacture Costs" KPIs. For further information on composite KPIs see [1].

Atomic KPIs are defined in our approach by using Structured English [13], based on the SBVR language proposal from the Object Management Group. Decision makers can use a special font which identifies business concepts involved in the definition of a KPI, as well as the relationship between them. In this way, decision makers may use the keyword[3] font, term font, Name font, and verb font to provide semantic definitions of KPIs. Each of these fonts provides a specific semantic meaning, which allows us to match business concepts with multidimensional elements without constraining their definition. Some examples of KPIs involved in our strategy are:

- "Increment in revenue", may be defined as a combination of two KPIs "Revenue in the current year" minus "Revenue in the previous year":
  - Total benefit in This year
  - Total benefit in Previous year
- "Number of vehicles sold", defined as: Total sales in This year.

As shown in the examples, and according to the SBVR specification [13], keyword font can be related to unary operations over measures, which allow us to aggregate the data obtained. On the other hand, term font can be mapped to metadata from the multidimensional schema, such as fact attributes and dimension attributes (properties), dimensions, and levels (concepts). Next, Name font is used to refer to individuals and exact values. As such, it can refer to instances of levels or exact numeric values. Finally, verb font can be used to mark verbs or prepositions. All these mappings are formalized in Section 4, in the form of a grammar which recognizes the language used to define indicators.

The benefits of following this approach are that (i) indicators can be defined in a user-friendly, controlled language, and (ii) they can be included into a Business Dictionary (BD), thus they can be referenced and queried by other applications, or used to generate documentation. This helps other decision makers into defining their own indicators as well as re-using existing ones.

[3] Font colors have been changed in order to improve the readability in grayscale color. SBVR original colors are: keyword, term, Name, and verb respectively

4 Validation using the Multidimensional Schema

Once we have defined a series of KPIs by using Structured English, they must be validated in order to guarantee that (i) the necessary data is stored in the DW, and (ii) the indicators are correctly defined according to the DW structure.

In order to perform the validation of each indicator, first, the multidimensional representation of the DW must be obtained (figure 3 and figure 4). The multidimensional information required are existing facts (center of analysis), fact attributes (measures, related to the performance of the business process), dimensions (context of analysis), levels and attributes of the dimension levels.

The first schema represents the information about budget asignation and actual costs ("QuadrantAnalysis" fact). The fact attributes included in this schema are the planned "Budget" cost for each entry, the real "Actual" cost, and the difference between them, "Variance". As context of analysis, we know information about each "Region", "Department" and "Position", allowing us to browse the assignations in the budget as we need.

The second schema represents the information available regarding the "SteelWheelsSales" process (fact). The fact attributes included in this process are the "Quantity" of each product sold, as well as the total amount of the sale, "Sales". Regarding the context of analysis, we have information about a "Product", such as its "Vendor" and the product "Line". Additionally, we also have information regarding "Customers", such as their name and address, the "Markets" where the sale was performed, the month of the year when the product was sold ("Time"), and the current status of the corresponding order (Cancelled, Delivered, On Hold, etc.).

These multidimensional schemata are used to (i) analyze if the concepts used by the decision maker to define KPIs do exist in the multidimensional models of

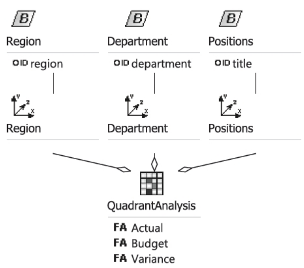

Fig. 3. (a) Multidimensional model for analyzing costs

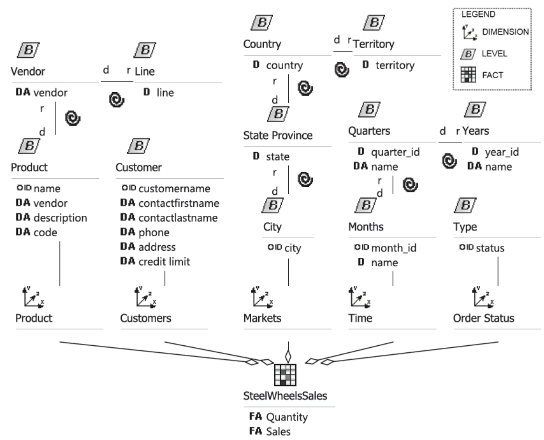

Fig. 4. (b) Multidimensional model for analyzing sales

the DW and to (ii) support the mapping from business concepts to DW elements. If a business concept has not been stored in the BD yet, the concept is matched against the multidimensiona schemata, asking for disambiguation to the the user if the mapping is not found.

After having identified the different concepts used by the decision maker in his definition, we proceed to translate the SBVR definition of the KPI into an OCL4OLAP representation [14]. OCL4OLAP is an extension of the OCL formal language, allowing us to query models which present a multidimensional structure (i.e. facts and dimensions). The translation of SBVR to OCL is considered to be a challenging transformation [2], since OCL does not consider concepts such as business rules. Since we focus on the definition of indicators, we restrain the possible transformations to definitions of indicators specified by means of formulas over multidimensional conceptual models. First, the definition of the specified indicator is recognized by the grammar described in figure 5, then, the indicator is translated to OCL4OLAP through the following process:

1. Values identified correspond with sets of cells in the cube specified by the multidimensional schema. By specifying a term corresponding to a fact attribute, the decision maker is implying that he is interested in operating with the value, thus a *dimensionalProject(cube::factattribute)* OCL4OLAP operation is performed. This operation extracts the relevant set of cells from the cube, allowing further operations to be performed.

```
Indicator -> Value ( Predicate )
Value -> ( Value BinaryOP ) Value1
Value1 ->  term
Value1 -> ( UnaryOP ) Value
Predicate -> ( Predicate AND ) Predicate1
Predicate1 ->  Dimension | Instance
Dimension -> Keyword1 Dimension1
Dimension1 -> term FactType1 term ( Condition )
Dimension1 -> term ( Condition )
Instance -> FactType2 Instance1
Instance1 -> ( Name OR ) Name term
Keyword1 -> by | of
FactType1 -> of
FactType2 -> in | of
Condition -> Keyword2 ( UnaryOP ) term ( CompOp Name )
Keyword2 -> with
CompOp -> equal to | higher than | lower than
CompOp -> equal or higher than | equal or lower than
UnaryOP -> sum | maximum | minimum | count | average
BinaryOP -> plus | minus | divided by | times Number
Number -> [0-9]*
```

Fig. 5. Grammar for recognizing indicators described using SBVR font.

2. Whenever an unary operation is performed over a given value, the corresponding OCL operation over the set of values previously projected is applied. These operations may be *sum()*, *count()*, or other unary operators.
3. Whenever a binary operation is performed over a pair of values, the result is obtained by iterating over the set of cells corresponding to each value. Therefore, a binary operation is translated to an *iterate(value1,value2,result=0 | result = value1 operator value2)* operation over the cube.
4. Predicates specify sets of conditions over certain dimensions, levels, and values. First, required dimensions are added to the query by means of *addDimension(Dimension,additivity)*. Then, the level of detail is adjusted though *rollUp(Dimension,level,additivity)*. Finally, conditions are translated by means of *sliceDice(cell | condition)*.
5. Once all the necessary operations have been performed, the initial aggregation function specified is applied (typically *sum()*), in order to obtain the value of the indicator. If no aggregation function has been specified, then, the default additivity function of the cube is applied.

After we have obtained the OCL4OLAP representation, we validate the correctness of the OCL constraint against the multidimensional schema. Since OCL4OLAP is an extension of OCL without the addition of new constructs, an OCL compiler can be used to validate the constraint. Finally, it is translated into a MultiDimensional eXpression (MDX[4]) query, as specified in [14].

5 Data Extraction

Once we have obtained the MDX representation for each KPI, their value is retrieved, loaded into the atomic KPIs, and normalized according to the values specified [6] for each of them. Afterwards, composite indicators are calculated, resulting in a comprehensive view of the business strategy including the performance associated to each element. The result can be seen in figure 2.

According to the results obtained, the Steel Wheels company is meeting its main goal (green light), increasing its revenue. As expected, since the company is focusing on the "Fancy Designs created" course of action, the KPIs point out that the "Low-Cost Designs" approach is performing overall between average and bad, presenting two indicators (*xg4* and *xg10*) with yellow light and one indicator (*xg3*) with red light. On the other hand, the "Fancy Designs created" approach is obtaining average results. This approach is exceeding the target amount of sales (*xg10*), but although the "# of complaints" is low (*s1* is active), the "Number of cancellations" is anormally high (*xg14* presents a red light), thus customer satisfaction may decrease, hurting the image of the company.

Our approach allows the decision maker to analyze the business strategy by using real-data, as opposed to estimations only. This allows the decision maker to identify potential problems in the business processes, e.g. there may be a potential problem in the distribution and delivery processes, as well as

[4] http://msdn.microsoft.com/en-us/library/ms145595.aspx

in the business strategy, e.g. despite average results in the delivery process we are meeting our goals in sales and revenue increase, have the problems in our delivery process not impacted our revenue yet?.

6 Related Work

We briefly present related work in the areas of KPIs and business models. In [15], the authors specify a series of Awareness Requirements over a requirements elicitation model of the DW, in order to model constraints which should be monitored, but pay little attention to analysis capabilities of the indicators and the process of providing such information to the user. Thus, as the focus of their work is on DW design, it can be considered as a complementary approach to ours. On the other hand, in [7], the Balanced Scorecard is proposed. The Balanced Scorecard has been one of the cornerstones in decision making for a long time. Its great advantage is that it maintains a global vision of the business strategy along with KPIs. However, this vision is not modeled, thus the relationships between strategies, goals and indicators are unknown. Furthermore, it does not provide analysis capabilities, such as those provided by dashboards. Dashboards [3] are proposed as means to provide a detailed view of certain KPIs. While dashboards provide detailed information about a subset of KPIs they are focused on, they lack a global view of business strategy, and must be manually implemented, introducing an overhead in the process and potentially introducing errors. Finally, Strategy Maps [8] describe how the organization creates value combining the different perspectives present in the Balanced Scorecard. However, are built in an informal way, and do not provide any mechanism to assess the effectiveness of the strategy modeled.

7 Conclusions and Future Work

We have presented a novel approach to relate KPIs defined in the business plan and the Balanced Scorecard [7] with business strategies and goals. Our proposal presents several advantages. First, all indicators are related to their respective goals, thus the decision maker can precisely identify which goals are having problems. Second, our approach not only allows the decision maker to model the business goals and indicators, but also allows him to analyze the business strategy using all the information in the underlying Data Warehouse, thus transforming the business strategy into a powerful dashboard. Third, KPIs are defined by using Structured English, allowing the decision maker to perform quick modifications, without requiring knowledge of how is the Data Warehouse structured at logical level. Finally, our approach supports a combination of real data and what-if analysis, allowing analysts to compare expectations with reported results, thereby helping them identifying existing problems.

Finally, since our approach involves decision makers in the process, we plan to test the approach by applying it to a real case study and evaluate the results obtained. We will focus on the interaction between decision makers and the system to analyze the effectiveness of using Structured English to define KPIs.

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