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REGULAR PAPER

A framework for the operationalization of monitoring in business intelligence requirements engineering

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Abstract Business intelligence (BI) is perceived as a critical activity for organizations and is increasingly discussed in requirements engineering (RE). RE can contribute to the successful implementation of BI systems by assisting the identification and analysis of such systems' requirements and the production of the specification of the system to be. Within RE for BI systems, we focus in this paper on the following questions: (i) how the expectations of a BI system's stakeholders can be translated into accurate BI requirements, and (ii) how do we operationalize specifically these requirements in a system specification? In response, we define elicitation axes for the documentation of BI-specific requirements, give a list of six *BI entities* that we argue should be accounted for to operationalize business monitoring, and provide notations for the modeling of these entities. We survey important contributions of BI to define elicitation axes, adapt existing BI notations issued from RE literature, and complement them with new BI-specific notations. Using the i* framework, we illustrate the application of our proposal using a real-world case study.

Keywords Business intelligence · Requirement · Monitoring · Indicator · Analytic · Field · Schema · Source

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1 Introduction

Business intelligence (BI) is a process whereby raw business data is turned into information that can be used to inform decision making and support management. Although BI is not a new concern [1], it has evolved over the past decade to include a wide set of complex tools and models which together enable us to handle heterogeneous data sources in businesses [2,3]. Such improvements have contributed to increase the quantity of information that is made available to decision makers. BI systems are now a technology capable of providing reporting solutions composed of dozens of indicators and dealing with aspects as varied as marketing, sales, operations, or logistics.

As the technology for making BI systems advances, the requirements engineering (RE) processes for this technology face new challenges. The need to identify stakeholders' expectations about a BI system to be (*BI requirements*), together with the need to specify how to satisfy those requirements (*BI entities*), and raise important conceptual and methodological issues. They also motivate the research presented in this paper.

The central question of this paper is *"What is the information (in terms of actions to be undertaken or objects to be implemented) that must be accounted for during requirements engineering of business intelligence systems (RE–BI) so that monitoring of the business is made possible?"* This question is directly related to the more general ones in RE, namely "How to ensure engineers collect and document adequately this information?," and "How the collected pieces of information can be combined to specify a system that best satisfies stakeholders' expectations?"

Given the specific analytical and reporting requirements of BI solutions, regular elicitation strategies may not be well adapted to answer our central question. In other words, there is a risk that some specific *BI requirements*, dealing with particular *BI entities*, are not treated adequately, because they are not familiar to engineers. This led us to identify the need to study how the information about these requirements can be collected, documented, modeled, and analyzed. Existing research focused on eliciting BI requirements [4], modeling performance indicators [5], and reducing the gap between business and BI-level understanding of a company [6]. Less attention has been paid to providing a broad perspective on the challenges related to *the operationalization of business monitoring*.

The present paper aims to fill in this gap by suggesting a framework that supports engineers during operationalization of BI requirements for business monitoring. The framework focuses on the problems of investigating the goals, functions, and constraints of BI systems. It aims to provide guidance about how to *elicit* and *model* information related to BI entities that can be useful in operationalizing business monitoring.

We use six BI entities: the *analytics* used to display information to decision makers, *indicators* used to build analytics, *fields* used to compute the indicators, *schemas* used to organize the fields, and *sources* used to feed the schemas. We argue these entities have properties that may not be accounted for by regular RE methods; for example, a regular elicitation method may identify the need for a particular source, but could omit details such as the update frequency, the calibration or the autonomy of that source, because that concept is specific to BI systems. We focus in this paper on the following RE for BI (RE–BI) objectives:

1. Identify and represent *BI entities*;
2. Model links between *BI entities*;
3. Model links between *BI entities* and *intentional business entities*;
4. Elicit important information about *BI entities*.

The contribution of this paper is twofold. Firstly, it discusses the concept of BI requirements, and how it can be elicited through the use of specific elicitation axes. Secondly, it describes BI entities that can be used to satisfy the BI requirements and provides formalisms for modeling the entities and the way they relate to provide monitoring capabilities to the business.

This paper is organized as follows. We start with a review of the literature (§2) and position our contribution as being within goal-oriented RE (§3). We introduce a list of salient BI entities, define their graphical notation (§4), and provide a running example (§5). Based on a literature survey, we propose elicitation axes to support engineers in collecting information about BI entities (§6). We then discuss the use of our framework in practice (§7) and present how the framework has been applied in BI industry, via a real-world case study (§8). We finally propose a discussion (§9) and a conclusion about the present and future work (§10).

2 Related work

The ability of software to perform and record measurements on business processes, and on other aspects of a business, is considered as an important opportunity in companies of all sizes [7,8]. To benefit from this opportunity, BI systems combine data gathering and storage, with analytical tools to provide relevant information to decision makers [3]. Considerable return on investment from BI systems is therefore expected [9]. This has led to research on, for example, ways to deliver quality BI [10], approaches to BI implementation [2], and on how to systematically relate BI to business activities [6].

BI systems usually consist of various data sources from which data is extracted via the extract–transform–load (ETL) approach. ETL extracts data from various data sources, applies transformations on it, and loads it into specific data structures such as, for instance, a data warehouse [2,11–13]. Online analytical processing (OLAP) applications typically run on a data warehouse to provide decision makers with views on data from different perspectives and on different aggregation levels [14,15].

BI contributes to the transformation of business data into information that can then be used by decision makers to derive knowledge [16,17]. Such position has been developed over years and is synthesized in the so-called DIKW hierarchy [18], a four-level pyramid composed of data, information, knowledge, and wisdom.

Advising firms about how to successfully implement BI is difficult. There is research on the definition of frameworks to support the selection of information under the form of key performance indicators (KPI) [19–22], with the goal to guide firms in the selection of information that does not only deal with financial aspects, but also with topics such as learning and growth, stakeholders. Broader methodologies aim to cover more kinds of data and information [8,23], but are not systematic enough to support RE activities. More structured approaches to BI have been proposed with the goal to represent some BI concepts in relation to the phenomena that the business aims to monitor. The ARIS methodology for instance can be used to represent indicators in business process management [24] and enables to assign indicators to relevant business objectives. Representation of BI entities in UML activity diagrams was also explored [25]. More recently, a framework [5] was suggested to formalize the concept of "indicator," together with its characteristics, relationships to other performance measures and relations to other common RE notions, such as goals, processes, and roles. In RE, the goal-oriented requirement language (GRL) was extended [26,27] to integrate indicators with the rest of the goal model. Moreover, addition of data elements to goal models has been suggested [28]. Modeling of indicators was also studied in an i*-like framework [6]. These approaches share some similarities with ours, as they formalize some BI entities and relate them to organizational elements. However, they seem to reduce BI entities to indicators and indicator-related concepts, which we will argue is limiting if we want to operationalize business monitoring requirements.

Common requirements elicitation techniques [29,30] are applicable to RE–BI. Research has also led to the definition of methodologies to support BI implementation [4,8,31–33]. These *BI roadmaps* agree in their recommendations and suggest, among others, to (i) study the application domain, (ii) understand what data is available, (iii) delimit the scope of the monitoring project, and (iv) define analysis and reports that are useful to end users. Although these roadmaps enable to collect relevant information about BI requirements, they do not provide formalisms to document clearly (i) important BI entities, (ii) the way these entities relate to each others, and (iii) the way these entities relate to business intentions. The combination of BI requirements elicitation and semi-formal notations has been proposed in various frameworks [15,34,35], but are specific to data warehouse requirements analysis and does not cover other aspects of BI such as, for instance, information delivery.

3 A goal-oriented RE–BI framework

The framework presented in this paper follows the basics of the goal-oriented RE paradigm [36]. Namely, we initiate the RE–BI process from the analysis of business goals, try to understand the rationale behind the BI system-to-be, and then suggest a way of collecting relevant information about the parts of the system to be that fit stakeholders' expectations. In other words, we consider that RE–BI should first handle the *why* question (why is monitoring necessary?), so that it can then address the *how* question (how to operationalize monitoring, or how to do monitoring?). Our approach translates into the *BI operationalization loop* (simply BI loop hereafter), presented in Fig. 1.

Reporting needs come from the observation that stakeholders often require feedback about regular *Business Goals*

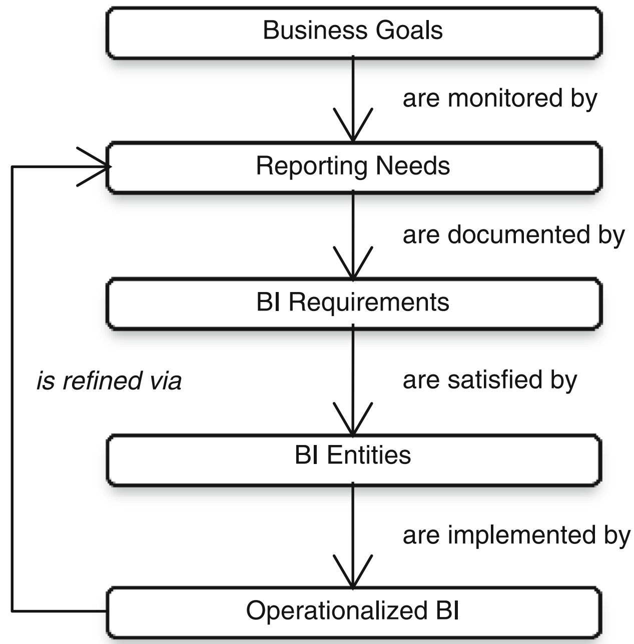


Fig. 1 The BI operationalization loop

in order to judge whether these goals are satisfied. Reporting needs reflect the need to keep track of business activities. Reporting needs are general: They simply provide the rationale behind the expected monitoring activity, for example, that we need to monitor the *sales process* because knowing about its status helps us anticipate sales and estimate future profits.

BI requirements are more specific, detailed, concrete version of reporting needs. They are obtained because reporting needs develop and become more critical to the firm. Unlike reporting needs, BI requirements are concise and clearly defined expectations of stakeholders about specific aspects of the monitoring activity. For example, the *sales process* reporting need mentioned above can lead to a BI requirement for the lagging monitoring of product margin and distribution costs.

BI Entities (analytics, indicators, fields, schemas, and sources) are the specifications, the building blocks for the BI system. They are to be seen as things needed to satisfy a BI requirement. For example, the lagging monitoring of the profit margin is a BI requirement that may be addressed by the specification of a BI entity such as a lagging margin indicator.

Operationalized BI is obtained when BI entities are actually implemented and related, so that they provide actual monitoring capabilities to the firm. Once such operationalization is achieved, feedback becomes available to the business. This in turn enables the firm to investigate new questions about its activities, and therefore leads to new reporting needs. For example, the firm learns its margin is decreasing and wishes to investigate why.

In this paper, our objective is to provide support to engineers for iterating through the BI loop and obtaining operational BI systems. Although relevant in the scope of RE, questions related to the evolution of a company's goal model due to the operationalization of monitoring and the related decision making outputs are not discussed here. They remain for future work.

The next sections define with further details each step of the BI loop. Section 4 introduces a meta-model of *BI entities* and how they relate to *operationalize BI*. Section 5 focuses on the rationale for the BI entities and describes examples of *reporting needs*. Section 6 presents a survey of the literature to support collection of information for the purpose of documenting adequately actual *BI requirements*.

4 BI entities

One way to support and structure discussions of BI requirements with stakeholders is to use BI roadmaps (see §2). The latter provide recurring questions that should be discussed, in order to move to a clearer view on users' context and expectations. A partial list of these questions is as follows:

– What data is needed? (Fields)
– How will data be obtained? (Sources)
– How will data be organized? (Schemas)
– What computations will be performed? (Indicators)
– What outputs will be shown? (Analytics)

These questions are domain independent. They relate to concepts that are central to *implement BI*, and they are what we call the BI entities.

4.1 What are the BI entities?

The *initial* RE–BI objective is to identify and model BI entities used to satisfy given BI requirements. This paper therefore suggests graphical notations for representing the BI entities. Table 1 summarizes these notations, together with definitions of the BI entities. Note that some of the notations presented in Table 1 are intentionally inspired by existing contributions on modeling of BI and KPI [6,25] or data warehouses [35]. Note also that a single BI requirement can require several BI entities in order to be satisfied, that is, there is a one to many relation between requirements and BI entities.

We use the DIKW pyramid (defined in Sect. 2) to further organize these entities and avoid omissions. Using DIKW has also the advantage of establishing clear hierarchical relationships between the BI entities. Table 2 reports the hierarchy and lists BI entities that we attach to each of its layer. Note that we do not report entities for the wisdom layer: We consider that this layer is more the result of decision making that requires human capabilities, which cannot be fully computerized. It is also important to note that we do not have a guarantee that our list is complete.

The hierarchy suggested by the DIKW pyramid (and which is represented by the sequence of BI entities in Table 1,

Table 1 Business intelligence entities

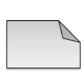
Entity	Description
	*Sources* are defined in this paper as mechanisms (processes, objects, software, etc.) that have as their only purpose to collect predefined data about one or more internal or external processes. Collected data are recorded in a repository (for instance, a data warehouse) under a specific *schema*
	*Schemas* are groupings of domain application concepts. They are usually used as a support for the multidimensional modeling implied by data warehouses or other BI repositories [11,14,31]. In this paper, a schema has a maximum of one *fact*, and usually one or more dimensions. BI repositories such as data warehouses or data marts typically require several schemas
	*Fields* are the representation of a process result and collected by a source and belonging to a schema. It can be a simple measurement of a business fact (i.e., a measure) [11,14,35], or a non-numerical field whose value is provided each time a measure is recorded (i.e., an attribute) [35]. Several related attributes can usually be gathered to form a dimension of the business
	*Indicators* are quantitative or qualitative evaluations of processes and are obtained from one or more fields or other indicators. They form complex measurements that are the result of computations/aggregations [37]. Indicators are intended to be used by decision makers and are real-world values which can be converted to normalized goal values in order to support decision making [6,26,37,38]
	*Analytics* are organized sets of indicators dealing with specific business issues. They can be regarded as user interfaces that organize and present information in a way that is easy to read and interpret [39]. They form the ultimate output of a BI system that are used by decision makers; for example, dashboards, scorecards, cockpits

Table 2 Alignment with DIKW definitions adapted from [18]

	Ackoff [16]	Zeleny [17]	BI entities
D	Symbols	Know nothing	Source, schema
I	Processed data	Know what	Field, indicator
K	Information put to use	Know how	Analytic
W	Evaluated understanding	Know why	–

from top to down) is the one we use to define relations between our BI entities. This hierarchy also reflects the actual BI implementation sequence as it can be observed in practice: Data are usually loaded into schemas under the form of fields which are then aggregated into indicators to build analytics.

4.2 How BI entities relate to each other

The *second* RE–BI objective deals with modeling the relationships between BI entities in Table 1 to show how these entities together enable to operationalize monitoring. For this purpose, we represent the entities in the meta-model in Fig. 2. The six classes generalize into a BI entity class, with a reflexive association on it. The association reflects the possibility for an entity to AND/OR/XOR decompose into other entities. Note that, by default, the ContType is AND.

The use of decomposition, represented in Fig. 3, is justified mainly by the fact that it reflects adequately the DIKW hierarchy between the BI entities. The sequence suggested by DIKW is enforced through the use of constraints in Table 3; for example, an indicator cannot decompose directly into sources, but only decompose into fields, themselves achieved through a schema, the latter being decomposed into one or more sources (the reader can refer to discussion in Sect. 9 for more nuance on that aspect). We do not make use of contribution links between BI entities, mainly because BI entities are dealing with clearly defined concepts which relate to each other through strict composition links; for example, an indicator does not "contribute" to an analytic, it simply is included (or not) in the latter.

The use of standard decomposition links, together with a mapping of BI entities to goal-oriented concepts, is also a way to support reasoning about entities. For instance, a goal reasoning approach such as [40] could be used, considering that BI entities are the implementation of BI requirements, themselves being present because of goals. Combining the meta-model with a subset of the propagation rules defined, there is therefore a way to reason about BI entities. Actually doing this remains for future work.

4.3 How BI entities related to business aspects

The *third* RE–BI objective deals with the modeling of links between BI entities and business intentions. In our meta-model, this is achieved by using two different type of links, namely control and contribution links.

4.3.1 Control links

A *control* relation is used to model the fact that a business element is monitored by a BI entity. The control may occur

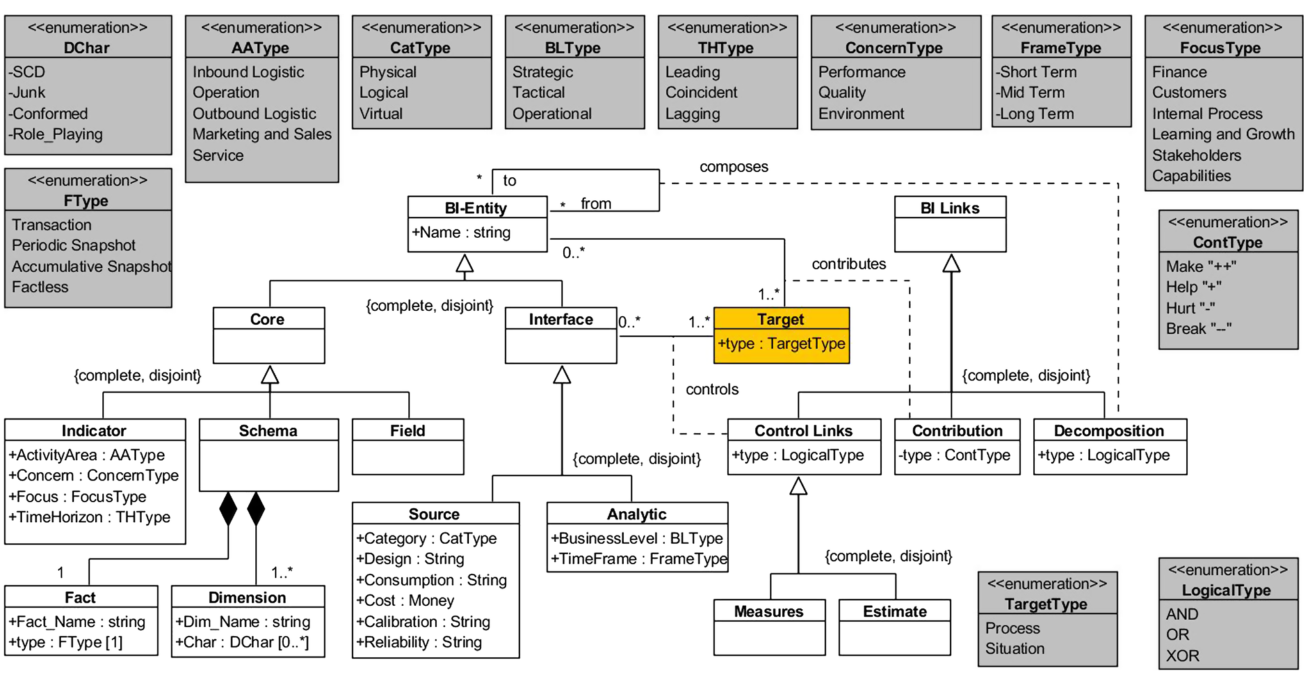


Fig. 2 A meta-model for BI entities and BI operationalization

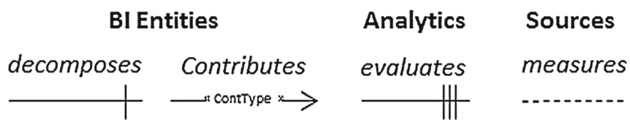


Fig. 3 BI links between BI entities and targets

Table 3 Constraints on the BI entities meta-model

Class	Constraint
Control	1.1 Sources measure process targets
	1.2 Analytics evaluate situation targets
	1.3 An analytic that evaluates a situation and a source (decomposed from the analytic) that measures a process imply there is a series of links from the process to the situation
Decomp.	2.1 Analytics decompose into indicators/analytics
	2.2 Indicators decompose into fields/indicators
	2.3 Fields decompose into schemas
	2.4 Schemas decompose into sources

in two different ways; when a source *measures* a situation, or when an analytic *evaluates* a process. The name of these links are adapted from BIM [6]. The two types of control differ mostly because they deal with different levels of the DIKW hierarchy. The measure link is used to express the fact that data are collected. This is the purpose of sources, hence constraint 1.1 in Table 3. The evaluate link is used to express the fact that knowledge is accessed to support decision making. This is the purpose of analytics, hence constraint 1.2 in Table 3. Constraint 1.3 ensures analytics are obtained using relevant data.

The target class represents the business aspects, or intentional elements, that the BI entities can control. We distinguish between two targets: situations and processes. *Situation* is defined as in [41]: It reflects organizational situations (domain assumptions), or intentional situations (goals, soft goals). *Process* refers to such things as tasks, business process, or any other concept dealing with how a *situation* is achieved. In this paper, instances of the target class are concepts from the i* framework. The idea with targets is to avoid mixing our meta-model with that of i*, or of any other specific RE modeling language. This opens up the possibility to use other RE languages such as GRL [42], TROPOS [43], or KAOS [44].

We distinguish BI *cores* from *interfaces*, because not all BI entities can control targets; for example, evaluating a situation with a field is not a BI best practice. The monitoring of a situation happens when a stakeholder is faced with analytics, used to support decision making. This evaluation would probably not be possible if the stakeholder was given a single field, or a standalone indicator. This is the reason why we distinguish between core entities and interface entities.

4.3.2 Contribution links

A contribution link is used to model the fact that a business element is somehow influenced by a BI entity. This contribution can be positive (i.e., the BI entity comes as a support for the achievement of the target) or negative, with varying levels defined in the ContType enumeration class in Fig. 2. Unlike control links, there are no restriction on contributions between BI entities and targets. For example, it may happen that the use of a "Margin" indicator helps to perform a particular task such as "List most Profitable Products." It is also possible that the use of a field such as "Marital Status" somehow hurts a "Respect Privacy" soft goal.

Contribution links strengthen the expressiveness of the framework. They enable to model alternative and provide some ways to relate BI entities (and among others indicators) to targets, such as suggested in many RE approaches that account for some of the BI entities [6,27,28]. Contribution links can for instance be used to provide information about how a process is fulfilled, or about how the use of a particular BI entity prevents the satisfaction of a situation. Like decomposition links, contribution links support reasoning methods such as those suggested in [35], but this aspect is out of the scope of this and remains for future work.

4.4 How BI entities are documented

The *fourth* and last of our RE–BI objectives deals with capturing relevant information about BI entities. The attributes reported in the BI entity classes, as well as the related enumeration classes, embody such information in our meta-model. They are explained in further details in our literature survey, in Sect. 6.

5 Reporting needs

This section provides examples of reporting needs and how they can be identified.

As a *running example* for the rest of this paper, consider the real case of PharmaShop (the name has been changed for confidentiality), specializing in the selling and distribution of generic drugs (ibuprofen, paracetamol, etc.). PharmaShop employs forty sales representatives organized across five teams, who are asked to travel across the country to sell products to professionals such as doctors, pharmacists, hospitals, and so on.

Recently, PharmaShop was facing business difficulties. In an attempt to overcome these difficulties, the board defined five critical strategic objectives, to be achieved within a year. They are reported in Fig. 4 under the form of an i* dependency diagram. Circles represent actors, rounded-corner rectangles represent goals, and rectangles represent resources.

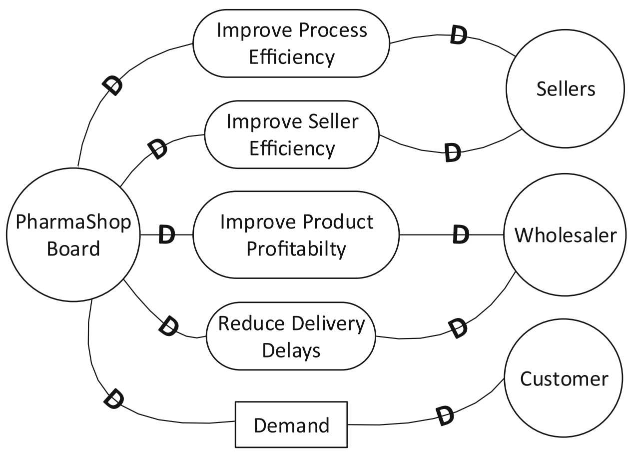


Fig. 4 i* strategic dependency model of PharmaShop

Table 4 Reporting needs of PharmaShop

Track	Reporting need
1	Monitoring process efficiency
1.1	Monitor elapsed time between a product entry and exit in the warehouse
1.2	Monitor number of lost or damaged products
2	Monitor seller efficiency and motivation
3	Monitor the margin for each product
4	Monitor delivery delays
4.1	Monitor elapsed time between a request made to the whole-seller and the related response
4.2	Monitor customers' complaints about long delays
5	Monitor the demand from customers

A link from one actor to another (passing by an intermediary node) represent a dependency; it means that the former actor depends on the latter for the accomplishment of the intermediary node. For example, from Fig. 4, we learn that PharmaShop board depends on the wholesaler for reducing delivery delays.

Goals and resources in Fig. 4 were critical for the survival of the company. The board therefore acknowledged the need to monitor the latter in a serious way. Initially, PharmaShop was using a set of fifteen "hand-made" indicators, but judged this solution was outdated. The firm wanted more analytical power and asked for a new BI solution. In the rest of this paper, we use the PharmaShop project to support the description of our RE–BI framework.

To support PharmaShop in achieving its strategic goals, we initiated the project with a definition of reporting needs. Together with the board, we defined some reporting tracks, reviewing each of the strategic goal. The reporting needs may totally or partially cover the business goals. Totally because a business may desire a system that monitors all the ins and outs of the goal; for example, PharmaShop wanted a total monitoring of the *seller efficiency and motivation* goal. Partially because it may happen that a business only needs some partial control of a goal. We see several reasons for this: (i) some monitoring solutions might already exist that must not be operationalized again, (ii) it may be too costly for the business to monitor all of its business goals or (iii) some aspects of a business goal may require interactions with other actors that are not possible. In the case of PharmaShop, measuring the delivery delay in a BI system requires collaboration of the whole-seller, who at that time had no desire to take part in such a process. In that case, reporting needs must be refined to something narrower than initial strategic goals.

The reporting needs of PharmaShop are reported in Table 4. Note that track 1 and track 4 are refined into reporting needs that are more specific than strategic business goals.

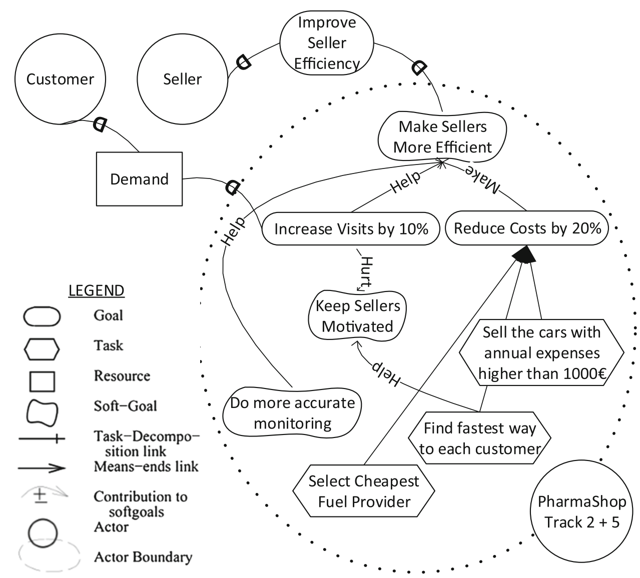


Fig. 5 i* strategic rational model of PharmaShop

Note also that Table 4 could be formulated under the form of a BI goal model. Note finally that such BI goal model is important, as it can be used to justify the evaluation of a business intention by some analytics, i.e., if there are no reporting needs, there cannot be any evaluation by analytics.

In the rest of this paper, we focus on track 2 and 5, which are concerned with the monitoring of the goal *improve sellers efficiency* and the resource *demand*. To better understand how these reporting needs can be satisfied, we provide an excerpt of the i* strategic rational diagram for the strategic dependencies *improve sellers efficiency* and *demand* in Fig. 5. The latter is used as a support for discussion in Sect. 6.

To achieve the *sellers efficiency* goal, PharmaShop has two alternatives; increase the number of visits by a seller *or* reduce the cost of visiting a customer. The first alternative implies that customers are asking for more visits, i.e., that there is a demand for visits. This is modeled with a resource *demand*. That alternative hurts the *sellers motivation* soft goal because the salary is fixed, regardless of worked hours. The second alternative implies to reduce representation costs: This can be achieved by reducing maintenance and oil costs, and by optimizing travels. The latter sub-task (optimization of travels) helps the *sellers motivation* soft goal (salary is unchanged for potentially less worked hours).

6 Elicitation axes

The main reason why we believed an operationalization framework for BI was necessary is that no tool has been designed that enables to deal with both the *modeling* of BI entities and *documentation* of BI requirements. We provided answers to the modeling concerns by introducing a hierarchy of BI entities and defining relationships between these entities, and between these entities and some intentional elements such as goals or soft goals for analytics, and tasks or resources for sources.

Because it is built according to the DIKW pyramid, we also believe our framework can be used as a guideline for the collection of information about BI requirements at the origin of BI entities introduced in Table 1. This section discusses some elicitation axes to document such requirements. As much of this work has already been done in separate contributions or domains, this section takes the format of a survey of literature. Note that the complete survey of relevant contributions for each concept goes far beyond the scope of this paper. This section should rather be seen as a review of some important aspects—hereinafter *elicitation axes*—to be addressed in some way during the RE-BI process.

6.1 Sources

A source is a generic concept, for things used to provide input to the BI systems. Broadly speaking, it deals with the collection and treatment (conversion, recording in database, etc.) of data. For the sake of usability, we make the assumption that a source directly records data into the schema (see Fig. 6). Thereby, we make transitional databases and ETL—which extracts, transform, and load data in the data warehouse—opaque to stakeholders, and argue that anything that comes upstream to the schema should be seen as related to the *data provider*. Engineers can refer to [45] for complements on ETL, to [46] for ETL modeling, and to [47] for a discussion on data source selection.

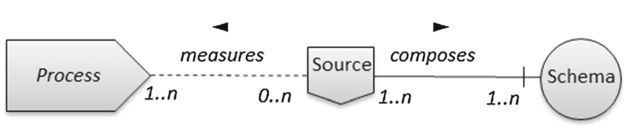


Fig. 6 Representation of sources and their relationships

Sources have been the center of considerable attention in context-awareness research [48]. They are defined as any *object that is capable of collecting regularly some simple measures about a given business process*. The main reason why we consider sources are relevant in RE-BI is that they provide data that ultimately will be used for the monitoring of business goals.

Consider the case of PharmaShop as illustrated in Fig. 5. Knowing that a source, for example, a *survey* of fuel price by providers and cities, has been identified to measure the task *select cheaper fuel provider*, an engineer might document that the resulting data can be used to estimate the achievement of the goal *make sellers more efficient*. This is acceptable, as the task seems to be a means to that goal, in agreement with constraint 1.3 from Table 3. Documenting this is relevant, as it may happen that an engineer is not aware of the source, and therefore of the validity of the data, and consequently uses it to illegitimately estimate another goal, namely that the engineer uses the survey as a source to monitor another strategic goal such as *improve product profitability*.

6.1.1 Categories of sources

Literature on context-aware computing typically distinguishes between three main categories of sources [49]:

- *Physical sources* are hardware sources capable of capturing almost any physical data. Examples of physical sources are numerous: light sources, microphone, accelerometers, touch sources, air pressure, location, gas sources [50];
- *Virtual sources* are software applications or services that do not measure physical data but use users' interaction to record new data. Examples of virtual sources are also numerous: electronic calendars, travel-booking systems, emails, keyboard input, mouse movement [48];
- *Logical sources* use several information sources (issued from physical and virtual sources) in combination with information from other data sources to solve higher tasks [48]. Example of a logical source is a trigger that detects user's current position by analyzing logins at desktop PCs and a database mapping of devices to location information [48]. Note that a logical source is not an indicator: it simply makes observations to provide data to the latter.

6.1.2 Properties of sources

Literature on context-aware computing also emphasizes important properties of sources [50], some of which are not to be omitted during RE-BI:

- *Portability, usability, and design* must be studied when using sources, and questions about size, weight, and physical robustness of sources are particular questions to be addressed with stakeholders;
- *Power consumption* may influence the availability of up to date data for the reporting solution and should be carefully considered;
- *Calibration* may represent constraints when sources need specific calibration or have a tendency to de-calibrate;
- *Reliability* of measurements that are recorded is obviously an essential aspect that should be discussed with stakeholders;
- *Price or cost* introduced by the use of additional sources or development of existing ones may influence other requirements and must be described.

While they are not exhaustive, the above lists provide some directions for elicitation of requirements about sources. For instance, it may be relevant for PharmaShop to think about the different sources they use, and what additional sources are required to monitor their goals. Given their objective to reduce travel costs, engineers may identify requirements for new GPS sources to keep accurately track of the movements of sales representatives. Documenting that this source is a physical one provides additional relevant information about its purpose/way of functioning. Questions about, for instance, portability (is the GPS heavy to carry?) or price (should the firm prefer low cost or expensive but highly reliable GPS?) are also relevant.

6.2 Schemas

The concept of schema, as it is conceived in this paper, is due to Kimball and Immon [11,12]. A schema refers to the specific structure that is used in the scope of a BI project to represent data, i.e., the so-called multidimensional structure. In this paper, we define a schema as the smallest possible multidimensional structure: one (and only one) *fact* and at least one *dimension*, i.e., a schema can be somehow seen as a preliminary version of the star schema [14].

Using schemas has some well-recognized advantages; firstly, it enables to present data in a user-friendly way [14]. Secondly, schemas are useful because they require less tables and less relationships than regular OLTP structures, which typically results in better performance of BI systems [11]. In other words, a multidimensional schema can be used to present data to end users in an intuitive way, with the only interactions being read-only queries [14]. Given our assumption that sources include transitional data bases, we can say that a schema captures directly its data from various sources. In this paper, schemas are used to provide fields—which will be further treated by reporting solutions to provide information to users—and are fed by sources (Fig. 7).

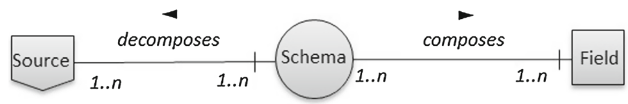


Fig. 7 Representation of the schema and its relationships

It is relevant to emphasize that we do not introduce facts and dimensions as separate BI entities, but as building parts of schemas that cannot exist by themselves (hence the composition relations in Fig. 2). The main reason for this is that, from the RE point of view, schemas deal with the identification and documentation of facts and dimensions, and of the possible connections between the two [15]. This suggests that schemas do not focus on data modeling: They just highlight the importance of eliciting facts and dimensions of the application domain during RE-BI.

Although there are many different approaches to dimensional modeling [51], schemas still involve research challenges [52]. Schemas have also been the center of some attention in RE (see for instance [13,15,53]). Some research has even developed goal-oriented requirements analysis methods dealing with the identification and documentation of specific BI requirements related to data warehouse (see GRAnD framework [35]). The latter provides a discussion about various concepts to be accounted for during the elicitation of requirements about data warehouse, together with some TROPOS notations.

6.2.1 Facts

A *fact* can be seen as the result of some usually low-level business goal achievements. Back in our running example, a fact could be the conclusion of a sale or the effective visit of a sale representative to a customer. The fact within a schema has a type. As this type likely impacts the way monitoring happens, it deserves to be discussed during RE-BI [11]:

- *Transaction fact* is the result of a business goal. It is atomic: It takes place at a precise moment, in a precise location; for example, the conclusion of a sale by a representative of PharmaShop;
- *Periodic snapshot fact* is a summary of many transactions over a given period; for example, weekly/year-to-date revenue of PharmaShop, for each day of the year;
- *Accumulating snapshot* is a summary of transactions over a given concept, with a delimited start and end date; for example, the total revenue from an order made by a customer of PharmaShop;
- *Fact-less* is a fact without measurable output and whose only goal is to reflect the association of several dimen-

sions; for example, the fact that a sale representative of PharmaShop visits a customer at a given date is a fact-less relation between three dimensions.

6.2.2 Dimensions

A *dimension* represents a point of view that can be adopted when looking at the fact of the schema. It provides a perspective on the fact and determines its granularity (i.e., level of detail of the fact). For the *sales* of PharmaShop, multiple dimensions can be used, such as the representative, the customer, the region where the sale was concluded, the product that was sold. It is possible to identify several characteristics of dimensions, which deserve to be discussed during RE-BI [11]. Note that a dimension can have several characteristics:

– *Role-playing dimension* represents a concept that can play several roles in the domain; for example, at PharmaShop, a *Person* dimension can be either a representative, a customer or an office employee;
– *Junked dimension* gathers several heterogeneous aspects of a fact (for example, details of a sale, such as sale category, sale language, sale format) could be considered as multiple dimensions but are gathered under one single-junked dimension;
– *Slowly changing dimension* is used when the business wishes to keep track of changes that occur in instances of the dimension; for example, when a customer of PharmaShop moves to a new place, the dimension keeps previous and current state of that customer;
– *Conformed dimension* is used consistently by several facts in potentially several different data marts; for example, the person dimension at PharmaShop is used consistently by both *travel* and *sale* facts.

Schemas are important to discuss because concepts they identify likely influence downstream reporting possibilities. Consider again the PharmaShop's *travel cost reduction* goal. Assume that one way to reduce these costs is to synthesize the accumulated traveled kilometers, collected via GPS sources, by-products, to find out which product requires the most traveled kilometers, and to adopt a particular selling strategy for it (for example, Internet or phone-based sales). This approach would only be possible if the engineer identifies correctly a "travel" fact and attaches to it—through a schema—the "product" dimension. Documenting, for instance, that the fact is an accumulative snapshot over products provides further insight about how the monitoring can take place; for example, *accumulated traveled kilometers* can only be represented using particular cumulative charts. Similarly, knowing that a dimension is slowly changing enables to provide monitoring capabilities, such as estimating the impact of a customer's relocation on its consumption.

6.3 Fields

While facts and dimensions in schemas are purely abstract elements to guide the modeling of data in BI systems, fields are much more practical entities that can be used as a first basic source of information for decision makers. Moreover, fields will likely be used in some predefined computations to produce more complex indicators. This places fields as a highly relevant BI entity to be elicited during RE-BI. Literature on RE-BI agrees on the existence of two distinct fields: measures and attributes [34,35]:

– *Measures* are numerical properties of a fact that describe quantitative aspects that are relevant for decision making; for example, the amount of a sale;
– *Attributes* are non-numerical properties whose value are provided when a fact is recorded to fulfill a goal; for example, the name of the sales representative responsible for the sale.

Given their fine granularity, there is little to document about fields during RE-BI. Details like aggregation behaviors [34,54] or data types could be considered, but are strongly related to data modeling decisions, making their discussion during RE-BI too premature. One challenge in eliciting fields is to correctly identify their respective facts and dimensions. Eliciting fields could for instance be achieved with a brainstorming session, in which stakeholders are asked to describe business elements they intuitively attached to identified dimensions. Note that we justify the distinction in notations between a schema and its fields mainly by the fact that it must be possible to compute an indicator based on several fields attached to one same schema (see Fig. 8); for example, two fields *traveled kilometers* and *total duration* from a schema *travel* can be used to compute an indicator such as *velocity*.

6.4 Indicators

An indicator is a quantitative or qualitative observation of a particular phenomenon. The phenomenon may be controlled by the business (such as a process or a goal) or be to the most extent beyond its control (economic conditions in a foreign country, government policies, change of legislation). BI indicators are indicators that are used to support decision making within a business, and that are computed from one or more fields and/or from other BI indicators (see Fig. 8).

To simplify the decision process, indicators can be converted from real-life to normalized goal model values. A

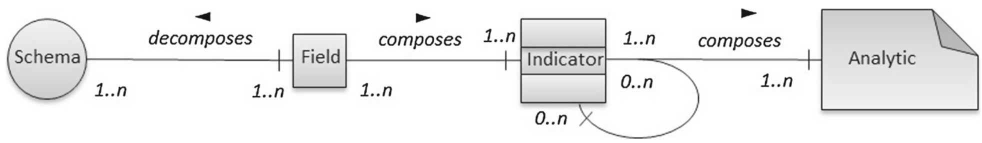


Fig. 8 Representation of fields, indicators, and their relationships

quantitative indicator for example can consist of a *current value* to be read against a *target(value)*, *threshold(value)*, and *worst(value)* which are usually ranging in $[-1; 1] \in \Re$ [37,55]. Conversion has also been formalized in the user requirement notation, which complements previous linear conversion methods with conversion functions for qualitative indicators [38,56].

Previous conversion methods contribute to make indicators easier to interpret for a decision maker. Examples of indicators in the literature are numerous: number of products sold, staffing costs [27], number of sales channels, number of promotions [6], employee satisfaction, process quality, technology stability [55], etc.

6.4.1 Focus

One of the first and today's most common characteristic of indicators is the focus of the indicator. By focus, it is meant the topic on which the indicator provides information. Some influential works on key performance indicators (KPIs) provide four of these focuses, that together form the well-known balanced scorecard [19,41]. Over time, other contributions have been suggested to complement the list of indicators focus (see for instance [21]). Most recurring focuses are [20,21]:

- *Finance*: information about growth strategy, profitability, and risk;
- *Customers*: information about value creation and differentiation;
- *Internal process*: information about various business processes;
- *Learning and growth*: information about the climate that supports organizational change, innovation, and growth;
- *Stakeholders*: information about who are stakeholders and what they need;
- *Capabilities*: information about people, technology, skills, and infrastructure that enable the processes.

6.4.2 Concern

A less common characteristic of indicators is the concern of the provided information. Concern can be defined as the problem dealt with by the information, the type of information that it aims to provide. Although not presented formally as an indicator characteristic in BI literature, concern seems to be relevant in RE-BI, as many managerial indicators do not deal specifically with performance [57–59]. The concern of an indicator is different from a control link, in that the latter enables to identify a target, while the former enables to tell what is monitored about that target. We see the following concerns as important:

- *Performance*: information about tasks in a process, which describes how well it is being performed;
- *Quality*: information about the deliverables of a process, which describe the quality of the deliverables;
- *Environment*: information about phenomena that are not under the control of the organization, that is, are not directly influenced by the processes of the organization.

6.4.3 Time horizon

The moment in time about which information is provided proves to be a common characteristic that is worthy to identify when eliciting requirements about indicators. Time horizon is concerned with the moment when the measured phenomenon is expected to happen and is often described as a property of indicators [20,41,55,60]. We see the following time horizons:

- *Leading*: information about future phenomena, i.e., expectations of what may happen in the future;
- *Coincident*: information about phenomena that currently unfold, i.e., what is currently happening;
- *Lagging*: information about phenomena that are no longer happening, i.e., what happened in the past.

6.4.4 Activity area

Another relevant elicitation aspect is the section of the business that is dealt with by the indicator. The activity area identifies the part of the overall value chain of an organization in which the indicators measure processes and/or quality. To categorize activity areas, we use Porter's value chain model [61]:

1. *Inbound logistics*: information about the receiving and storing of externally sourced materials, parts, data, or anything else used in running the business;

2. *Operation*: information about a task or process involved in the manufacturing of a product/service;
3. *Outbound logistics* information about the activities associated with getting finished goods or services to buyers;
4. *Marketing/sales*: information about the communication activities to consumers about products or services, of purchasing behavior of the consumers;
5. *Service*: information about the interactions with consumers after the product is sold to them.

These four elicitation axes (focus, concern, time horizon, and activity area) reflect the importance of indicator concepts within BI systems. They are in fact the building blocks of any monitoring system, and it is well accepted that their design is critical for the success of the entire reporting system [22,23]. Previous axes come as guidelines for telling engineers what kind of indicators they face, and which they omit to use.

In the case of our running example, stakeholders may ask for some information about efforts that are made by sales representative to actually sell their products. The engineer may document a BI requirement for an indicator. The question that must then be answered is what indicator must be implemented? Or in other words, what do stakeholders expect from the indicator? Using the elicitation axes, an engineer could discuss with stakeholders and document an expectation for finance-oriented indicator (focus), centered on the process (concern), built on historical data, in a lagging way (time horizon) and dealing with a mix of sales and outbound logistic processes (activity area). After the review of these elicitation axes, the engineer could document the need for an indicator obtained from previous fields such as *traveled kilometers* and *total duration*, the combination of which provides information about the total *travel effort* made by representatives.

Indicator elicitation axes also come as dimensions for diversifying indicators and covering as much as possible of the business aspects. This position is already well accepted for the specific case of the *focus* dimension (see literature on balanced scorecard [19,20]). It is less evident for dimensions such as *time horizon* or *concern*. Yet, these may be relevant to ensure that one BI system covers, respectively, all past, present and future aspects of the firm, or deals with all processes, quality, and environments issues. This does not mean that a reporting solution must cover each level of each axis: The idea is rather that the dimensions can be used as a guide to determine what is covered by the reporting solution and being aware of what is not covered.

6.5 Analytics

An "Analytic" is an interface for users of the reporting system to access information. It forms an important component of BI systems [31]. It can be defined as *a relatively small collection*

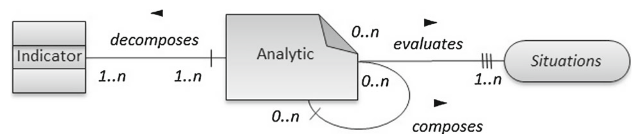


Fig. 9 Representation of analytics and their relationships

of interconnected key performance metrics and underlying performance drivers that reflects both short- and long-term interests to be viewed in common throughout the organization [62]. Our framework supports the fact that an analytic can be composed of other analytics, under the form of nested analytics (see Fig. 9). Although analytics are common in practice and form one of the most visible output of a BI system, there is limited research on analytics, and many open questions still need to be addressed in order to obtain a clear view on the various success factors of analytics [63]. It is therefore difficult to identify elicitation axes for analytics as we did for other BI entities.

6.5.1 Time frame

A first property of analytics is related to the time frame that can be adopted when interpreting the analytic [64]. We see three different time frames:

– *Short term*: deals with phenomenon that will happen within a short period of time (e.g., a day);
– *Mid term*: deals with phenomenon that will happen within a medium period of time (e.g., a month);
– *Long term*: deals with phenomenon that will happen within a long period of time (e.g., a year).

6.5.2 Business level

An important characteristic which is recurring in literature on analytics [64,65] is the business level that is dealt with by the analytic. We see three such levels:

– *Operational analytics*: enable front-line workers to manage and control operational processes;
– *Tactical analytics*: enable intermediate, departmental monitoring of large processes and projects;
– *Strategic analytics*: enables high-level evaluation of how the business does and where it is compared to set strategic goals.

We believe the business level is important to discuss because it intrinsically deals with many of the characteristics of an analytic (display, visualization tools, etc.). Research should, however, go into the identification of additional elicitation axes to achieve more complete elicitation of analytics. Note that analytics can be characterized by properties of indicators it is composed of; for example, an analytic can be also lagging, with a performance concern. This, however, is decided at the level of indicators and is neglected in analytics.

Considering the previous *travel effort* indicator, an engineer could elicit a BI requirement according to which the indicator must be included as part of an *operational analytics*. [64] provides some indications about what should be included in such analytic. Hence, the engineer could specify an analytic that lists, hour by hour, each of the records of the GPS tracker, in addition to some information about sales numbers. The specification for a *strategic analytic* would have been different; for example, the analytic should have been graphical, with summarizing illustrations, analytical capabilities and visual indicators such as gauges or maps.

7 BI entities in practice

Previous sections introduced notations for important BI entities and suggested important axes of elicitation. Together, these aspects form a framework for the elicitation of BI requirements which ultimately can help the RE of BI systems by acting as a checklist. Four important remarks should be made about the framework.

Firstly, it remains mainly conceptual, in the sense that it does not discuss practical entities: The framework provides notations and elicitation approaches to document these concepts in a semi-formal way. In fact, BI entity from the framework should be seen as a meta-concept, the instances of which form the entities summarized in Table 5. We do not distinguish between these concepts because, from an RE perspective, they deal with the same type of BI requirements. Each of the elicitation axes needs to be considered for each instance of the BI entities. Table 5 lists what we see in terms of real-world entities inside BI entities concepts.

Table 5 Examples of some BI entities in practice

BI entities	Examples
Sources	PDAs, SmartPhones, Tablets, ERP, CRM, RFID, Apps, Web-Services
Schemas	Data warehouse (DWH), data mart (DM), operational data store (ODS)
Fields	Measures, facts, number, value, score, counter, date, name, gender, location
Indicators	Key performance indicators (KPI), key risk indicators (KRI), key result indicators, economic, and financial indicators
Analytics	Dashboards, scorecards, cockpits, listings, reports, sandbox

Table 6 Methodologies for BI entities implementation

Methodologies	Sources	Schemas	Fields	Indicators	Reports
COBRA-ONT [66]	X				
Context architecture/awareness [48,67,68]	X				
MDA-DW [69]	X	X			
Dimensional modeling [11,12,14]		X			
DWARF [15]		X	X		
ETL modeling [46]	X	X	X		
GRAnD [35]		X	X		
DFM [34,54]		X	X	X	
Modeling of indicators [5]			X	X	
URN [26,38]			X	X	
BIM [6]/reasoning with indicators [37,70]				X	
BSC [7,19,23,71]				X	X
Dashboarding [39,62,64,65]					X

Secondly, the framework does not provide (and does not aim to do so) a methodology for the implementation of BI entities, but rather suggests a list of aspects or characteristics that deserve to be discussed with stakeholders in order to report BI requirements about these entities as clearly as possible. Given the high-level approach of the paper, the framework remains vague about how the BI entities must be implemented. We believe, however, that it is relevant to pay a minimum of attention to this aspect, given the RE focus of this paper. Since a lot of work has gone into the definition of methods to implement BI entities, we simply list some of them in Table 6.

Thirdly, the framework may appear to be too restrictive with regards to connections between BI entities and business intentions, i.e., we are conscious that in practice, an indicator could also be used to directly *evaluate* a business goal without the intervention of an intermediary analytic. That position may somehow burden RE activities, but helps improve completeness of BI documentation. For instance, the use of an indicator to evaluate a situation requires necessarily the use of a dummy analytic. The reason for this is that each BI entity suggests a list of aspects that should be documented (see Sect. 6). Imagine now indicators or fields control directly some intentional elements; this would represent a risk of missing important documentation aspects, as the analytic's elicitation axis would not be accounted for. For example, there would be a risk to omit questions related to

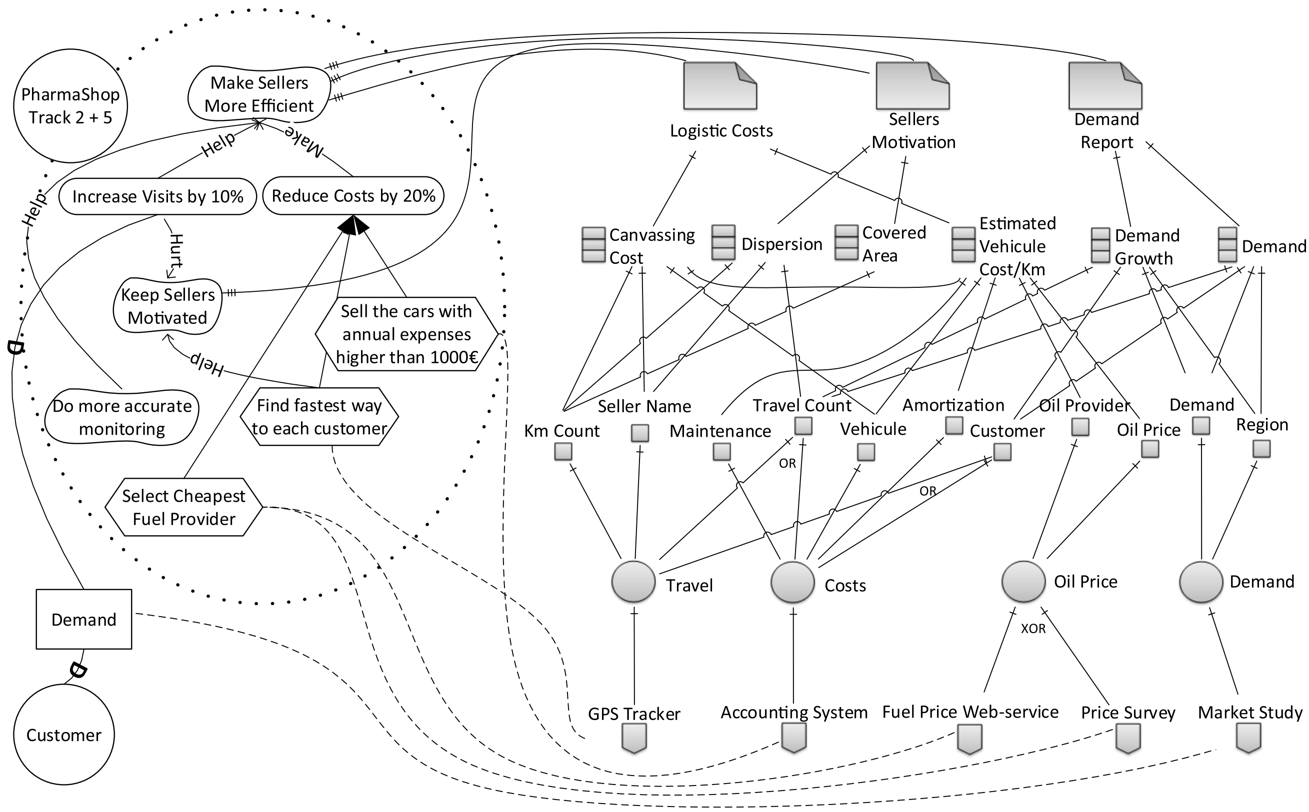


Fig. 10 Operationalization of reporting track 2 and 5 at PharmaShop

how the indicator should be presented, to who it is addressed in the company, etc. In other words, the use of interfaces comes as a guard rail for better completeness of BI documentation.

Fourthly, the framework does not provide any mechanism for ensuring the set of identified BI entities is sufficiently complete. For example, there is no way to ensure that a sufficient number of sources has been considered for building an analytic that accurately evaluate a particular situation. As an illustration, consider the model presented in Fig. 10, in which a goal "Reduce Costs by 20%" can be achieved by "Select Cheapest Provider," "Find fastest way to each customer," etc. With the framework, it is possible to attach an analytic to that goal, which only decomposes into one single source such as "GPS Tracker." In that case, we obtain a model in which the goal is evaluated by an analytic which information comes from only one sub-task of the considered goal. The point here is that the framework, as it is currently defined, does not ensure completeness of the sets of BI entities that are used. It simply ensures that requirements from those BI entities, which are already identified, are correctly documented. It is therefore the duty of the engineers to ensure that the identified BI entities are sufficiently complete to ensure adequate evaluation of business situations.

8 Case study

This section illustrates how our framework has been used in the case of PharmaShop. The case study focuses on the strategic dependencies *Make Sellers More Efficient* and *Demand*, which as a reminder are only parts of a broader strategy adopted by the company to overcome financial difficulties (see Fig. 4).

The case study is structured according to the BI loop introduced in Sect. 3. It first (i) discusses reporting needs, (ii) shows how BI requirements were documented, (iii) specifies BI entities and (iv) relates BI entities to operationalize monitoring. As already discussed, it usually requires several iterations in the BI loop to reach an adequate documentation. Most of this case study deals with the first—and most important—iteration. A subsection, however, provides some discussion about additional iterations in the loop.

Our objective is to support elicitation of information about salient BI entities. This implies that the information about entities must be adequately documented. As we expect documentation to be clear and easily accessible for subsequent use, we suggest the template in Table 7 for documenting BI requirements, i.e., the template is a *definition standard* for any BI requirement. Note that our template is inspired by—and comes in addition to—documentation formats such as

Table 7 Template

Name	Name of the instance
Type	Name of the entity
Sub-type	Practical definition of the entity (Table 5)
Stakeholder	Agent who gave the information
Timestamps	Time when the information was collected
Characteristic	Specifications according to elicitation axes
Controls	Other instances controlled by the instance
Composes	Other instances achieved by the instance
Description	Informal description of the instance

those suggested in RE literature for goals [44] or soft goals [72].

8.1 Defining reporting needs

Reporting needs of PharmaShop have already been discussed and are reported in Table 4. As a reminder, we focus on reporting track 2 and 5. Reporting needs deal with targets—in our case, i* goals, soft goals, resources and tasks—represented on the left side of Fig. 10.

8.2 Analyzing BI requirements

8.2.1 Analytics

Reporting needs suggest some BI requirements which are to be discussed with stakeholders. As the framework is goal oriented, we started from business goals and tried to identify related BI requirements, i.e., analytics' requirements. We then went downstream according to the DIKW pyramid. Guided by the i* model in Fig. 10, we questioned stakeholders about which analytics they would use to monitor the achievement of the *sellers efficiency* goal. We focused on that goal because of the reporting needs in Table 4, i.e., track 2 justifies the need to monitor efficiency and motivation, and so indirectly expresses the need for analytics.

The discussion was guided by the different alternatives identified in the i* model as means end to the main *sellers efficiency* goal; for example, we asked questions not only about representation costs, but also about the number of visits alternative. From there on, it appeared that only one analytic was necessary: a *logistic costs dashboard*. At that moment, we had no idea of the extent to which that analytic was able to cover each possible alternative for the strategic goal. This had no particular bearing, as RE-BI is iterative (the rationale behind the other analytics reported in Fig. 10 is detailed below).

There may not be a one-to-one relation between things to be monitored and analytics; for example, there may be more than one analytic for the *sellers efficiency* goal. It is actually up to the stakeholders to decide how important a given goal is, and what effort is required to evaluate it. At that moment, we were not concerned about how the analytic was to be built. We were simply concentrating on the evaluation of the targeted goal: the purpose of the identified analytic was to monitor the *make sellers more efficient* goal.

Once the required analytic was identified, we used our elicitation axis to collect information about the latter; for example, we focused on the definition of the *business level* at which the analytic was expected to work. As an illustration, consider the definition of *logistic costs dashboard* in Example 1. Given the specifics of each team of representatives (customers localization, different vehicles, different visit assignments, etc.), we documented the need for a tactical dashboard. The latter had to be computed separately for each team. PharmaShop's board insisted on the importance of having visual representations, because they likely have more impact on sales representatives, hence the dashboard.

Example 1 Logistic costs

Type: analytic;
Sub-type: dashboard;
Stakeholder: Mr. Dupont, PharmaShop's CFO;
Timestamps: 11/05/2013;
Characteristics:
Business level = tactical;
Time Frame = long term;
Controls: make sellers more efficient (evaluates)
Composes: /
Description: evaluates the *seller efficiency* goal. Computed for each team. Must be visual, and will be addressed to sales representatives.

8.2.2 Indicators

The analytics being clearly defined, we then focused on indicators to be used as building blocks for, for instance, the *Logistic costs dashboard*. Based on methodologies listed in Table 6, we identified a first indicator: the *canvassing cost*. That indicator is documented in Example 2.

Example 2 Canvassing cost

Type: indicator;
Sub-type: key performance indicator;
Stakeholder: Mr. Dupont, PharmaShop's CFO;
Timestamps: 11/05/2013;
Characteristics:
Focus = finance;
Concern = process;
Time horizon = lagging;

Activity area = outbound logistic, sales;

Controls: /
Composes: logistic costs dashboard;
Description: provides information about what it costs for a representative to visit customers. Is computed from *estimated vehicle cost/km* in combination with the *Km count* field, and ventilated according to vehicles and sellers name.

During the elicitation, we insisted on the need to account for additional indicators, claiming that one indicator is not enough to build a dashboard. Hence, it turned out that *canvassing costs* was computed from another indicator, *estimated vehicle cost/Km*, which in turn had to be reported in the dashboard.

After the documentation of the *logistic costs dashboard* and its related indicators, it appeared that the former analytic was strictly built on lagging, financial and process-oriented indicators. Consultation of PharmaShop's board confirmed its interest in having only financial indicators, which they said are lagging by definition. They, however, acknowledged the necessity to include indicators dealing with alternative *concerns*, and suggested to include a *demand* indicator, dealing with environment concerns. The latter should provide indications about expected customers' willingness for more visits (Example 3). For convenience, the board required that *demand* indicator to be included in a distinct analytic called *demand report*.

Example 3 Demand

Type: indicator;
Sub-type: economic indicator;
Stakeholder: Mr. Dupont, PharmaShop's CFO;
Timestamps: 13/05/2013;
Characteristics:
Focus = customer;
Concern = environment;
Time horizon = leading;
Activity area = marketing/sales;
Controls: /
Composes: demand report;
Description:estimation of customers' willingness for addi tional visit (number of visits and expected growth in %). It is obtained from a customer-independent demand measure which is weighted according to the effective number of visits for a given customer.

8.2.3 Fields

The final set of indicators being defined we focused on the identification of fields that were required in order to compute the idicators. As indicators corresponded to existing management measurements, the definition of these underlying fields was well known by the stakeholder, and therefore well documented. For instance, it is common at PharmaShop to compute the *canvassing cost* (Example 2) based on a *km count* (Example 4) and indirectly on *oil price*, *amortization* and *maintenance cost*. In addition, other fields like *travel count* or *demand* has been documented. The latter were important in that they supported the establishment of the *demand report*.

Example 4 Km count

Type: fields;
Sub-type: measure (counter);
Stakeholder: Mr. Dupont, PharmaShop's CFO;
Timestamps: 14/05/2013;
Characteristics: /
Controls: /
Composes: canvassing cost, dispersion, covered area;
Description: number of kilometers traveled between the departure from PharmaShop's offices/a customer to the next customer/PharmaShop's offices.

Other fields—with *attributes* as sub-type—were also defined to add dimensionality to the indicators. Hence, fields like *region name*, *vehicle registration plate* or *customer name* were added to the list of field requirements. Note that, for sake of readability, Fig. 10 does not represent any field dealing with the time dimension: in fact, each idicator uses at least one field dealing with time.

8.2.4 Schema

Fields are not independent: They relate to each other through the concept of schema. Considering for instance a field like *travel count*: that field would not mean anything to PharmaShop if not associated with the seller doing the travel. Hence, we identified a need for a *travel* schema. Using our elicitation axes, we interviewed the board to document most relevant *dimensions* to be attached to the central *fact* of the schema, i.e., travel. As a reminder, it is worthy to note that eliciting schemas is important in order to identify significant business concepts; it should under no circumstance be seen as an actual data modeling activity, which will likely take place latter in the process of designing the BI system. Results are reported in Example 5.

Example 5 Travel

Type: schema;
Sub-type: star schema;
Stakeholder: Mr. Dupont, PharmaShop's CFO;
Timestamps: 15/05/2013;

Characteristics:
Facts = travel;
Dimensions = time, employee, customer;

Controls: /
Composes: Km/travel count, seller/customer name;
Description: collection of data dealing with the trips of emplo yees to visit customers.

8.2.5 Source

To end up with the first iteration, we focused on the collection of data to feed the schemas. This collection is achieved through the use of sources. The case of the *Km count* field is interesting to discuss, as at the time when this analysis occurred, PharmaShop had no way to measure it. We therefore defined the need for a new *GPS Tracker* source. Based on our framework, we analyzed some of the stakeholders requirements about this source. Results are reported in Example 6.

Example 6 GPS Tracker

Type: source;
Sub-type: GPS device;
Stakeholder: Mr. Dupont, PharmaShop's Chief Financial Officer;
Timestamps: 16/05/2013;
Characteristics:
Category = physical source;
Properties = low portability, high usability, low reliability, low price;
Controls: optimize traveled distance;
Composes: travel (schema);
Description: a device placed in the representative vehicle, that keeps track every minute of the representative location (stakeholder accepts 100 meters accuracy). Only works in Belgium. Possible to buy additional maps.

There are several additional observations to be made about sources. First, it should be noted that sources are not mandatorily IT/mechanic solutions such as information systems or trackers. As an example, consider the *price survey* and *market study* sources, which are actually human sources. Second, an example of XOR decomposition is provided in Fig. 10: The oil price schema can be obtained either by the use of a web-service, or by the survey of prices for the different oil providers. The use of both sources would be redundant, costly, leading to data inconsistencies, and should therefore be avoided. The decision of selecting one source rather than the other can be supported by contribution links, as illustrated in Sect. 8.5. Thirdly, although sources are usually associated with the measurement of business processes (tasks in i*), they can also be used to measure the availability of a resource, such as the market survey.

8.3 BI entities and monitoring operationalization

Based on the requirements identified in the previous phase, we built a first model of the operationalization of monitoring at PharmaShop. In the case of PharmaShop, most of the requirements were satisfied using one single BI entity; for example, the Km count requirement (Example 4) is satisfied using a single Km count measure. We started the operationalization by specifying those standalone entities.

In a second phase, we handled the BI requirements whose fulfillment could not be achieved using a single BI entity. For instance, Example 3 cannot be achieved using a single indicator: PharmaShop had a requirement for an indicator presenting the demand under the form of a growth rate (in %) and number of demanded visits (units). While that expectation can be modeled as one single BI requirement, it is not possible to satisfy it using one single BI entity. We therefore specified two distinct indicators, *demand* and *demand growth*, both dealing with the demand indicator requirement (see Fig. 10).

The need for several entities depends on stakeholders monitoring intentions. It is usually not clearly stated in the requirement template, but is somehow explicit in the description of the requirement.

A last stage consisted in linking the various BI entities and implementing them in order to actually provide monitoring capabilities. This is done by using control links between BI interfaces and targets and decomposition links between BI entities, as illustrated on the right side of Fig. 10.

8.4 Further iterations

After the first iteration had been concluded, we met the stakeholders for a debriefing. The objective was to show them which of the goals/soft goals of the company were actually evaluated by the resulting BI specifications. It turned out for instance that the *seller motivation* soft goal was not evaluated in the first iteration. As a consequence, we introduced through a second iteration a new analytic composed of some new indicators. All the new indicators were themselves decomposing in already documented fields, schemas, and sources. That process reflects the use of the BI loop discussed in Sect. 3.

8.5 Accounting for contributions

Although the focus of the paper is not on reasoning about BI entities, it is interesting to see how contribution links of the RE-BI framework can be used as a support for the selection of alternatives in a BI solution.

Consider as an example the case of the *oil price* schema, which decomposes into either *price survey* or *fuel price*

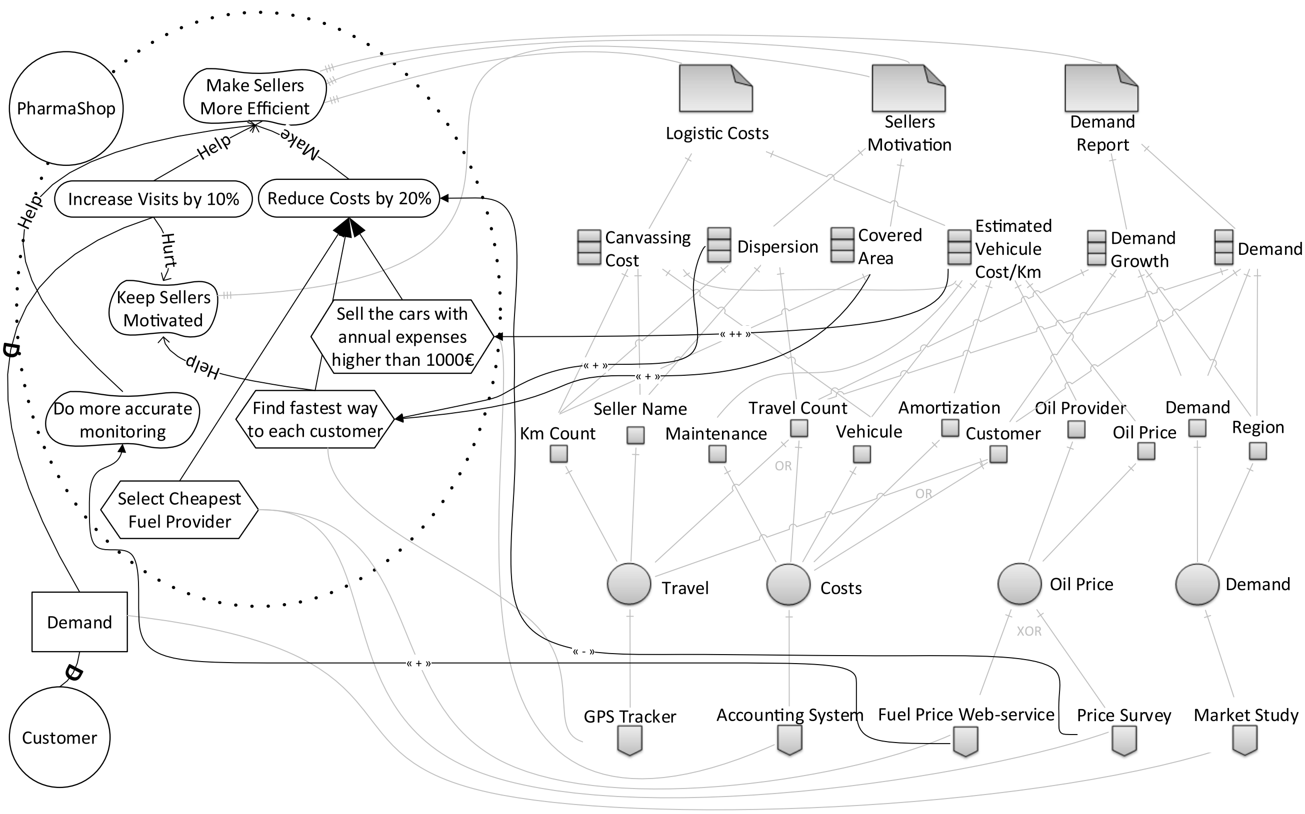


Fig. 11 Operationalization of reporting track 2 and 5 at PharmaShop—using the contribution links

web-service. Only one of these two sources will be implemented in the future system (this is modeled in Fig. 11 with a XOR).

Contribution links offer support to decide about which source to use (see Fig. 11). For example, the price survey is an alternative that hurts the business goal "Reduce Costs by 20%," because it requires much time to collect and treat oil prices from each possible provider, and therefore implies many resources to be consumed. On the other hand, the web-service source helps the "Do more accurate monitoring" soft goal, because it measures data directly from the provider. The reasoning here is simple and suggests to select the web-service alternative. With larger models, such reasoning may become more complex and require more systematic approach (see for instance [35]). As already discussed, this is a way for future research.

Similarly, contribution links are represented between indicators and some tasks from the i* model, to model the fact that the indicators support the fulfillment of the tasks. For instance, the fulfillment of the task "Find fastest way to each customer" is somehow supported by the indicators dispersion and covered area, despite the absence of control links between the indicators and the tasks. Contribution Links could also be used to decide about alternative indicators to be used in an analytic.

9 Discussion

The framework proposed in this paper suggests a set of concepts and relations, some of which have been suggested in other works. Our approach, however, differs from the latter in that it focuses on completeness and documentation of information for RE–BI and adopts a broad perspective on the various entities required to provide actual monitoring capacities to a business. As already argued, existing approaches-e.g., BIM, BI roadmaps—do not cover entirely these aspects (and do not aim to). The framework comes as an answer to this gap. It should also be noted that, as described in the BI operationalization loop, the process is iterative. It should not be seen as a one-shot approach, in which the design of the system is totally decided and then be interrupted. Our RE-BI framework should rather happen in an agile way, all along the BI project life cycle.

The analysis presented in this paper should be seen as an exploratory study: It shows how our framework can be used and ensures that it fits actual BI practices. However, no mechanisms were implemented during the analysis to compare the output of our framework to output that could be obtained using different BI approaches, i.e., while the PharmaShop project ended up with a BI system that satisfied requirements of the stakeholders, we have no way to show our RE-BI framework is better than another. In other words, our case study simply shows the feasibility of the framework. We acknowledge it is insufficient to conclude our approach is actually better than another one, and we are conscious that further validation is required to fully justify our framework.

It is also important to take into considerations the limitations of our approach. Firstly, the list of our BI entities is obtained from a literature survey, not from an empirical study about actual BI practice. As a consequence, the list may not be perfectly representative of actual BI concerns, and additional BI entities may be identified in the future. Secondly, the elicitation axes defined in our framework reflect the most important aspects to be discussed during RE. An axis is considered important when it is widely discussed in BI literature. This suggests that our framework may not account for some less covered axes of BI entities which may still be critical for the success of a BI project. These limitations, however, do not hold us back from drawing relevant conclusions about how RE-BI should happen, and what pitfalls should be avoided.

10 Conclusion and future research

In this paper, we discussed the importance of accounting for the specifics of BI solutions when doing RE. We stressed the fact that no global perspective has been proposed to engineers, which defines a set of concepts to be dealt with when designing and operationalizing the requirements of a BI system. As an answer, this paper proposes a framework that, based on a review of literature on BI, suggests a list of salient BI entities that are of primary interest for requirements engineers.

We provide a modeling framework to support the identification and documentation of these BI entities. The framework is to be used in parallel with any goal modeling language: We use i* in the case of this paper. The framework suggests that some BI entities decomposes into other BI entities to build an actual BI system. We illustrated how the framework can be used throughout a running example and a case study.

Further ways for research include the development of a supporting tool, as well as a comparison of the method with other plausible RE-BI approaches. Future work could also concentrate on the improvement of our list of characteristics, for each BI entity, in order to provide additional support to BI practitioners. Last but not least, the study of existing propagation rules for reasoning about BI entities is also a promising research question that deserves particular attention.

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