Aligning Business and Software Processes: GQM+Strategies Revisited

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***Abstract*—GQM has proven itself useful in supporting the definition and execution of software measurement plans. However, GQM has not been as effective in supporting the need for linking software measurement goals to higher-level goals, which typically originate in the business world. Hence, the GQM+Strategies technique was proposed to explicitly linking software measurement goals to the business world. However, little attention was given to the description of the business world. In this paper, we propose a method to precisely describe the business domain and its characteristics, the business goals, the strategies, their relationships with the software activities carried out to support the strategies, and how strategies are selected. We propose a way to firstly describe the business world, including business and software processes, and secondly to specify the measurements to be carried out. The proposed approach has been applied to a case proposed in the literature. The proposed approach proved very effective in supporting the investigation and descriptions of the business world. The creation of measurement plans according to the GQM+Strategies technique was greatly eased.**

Keywords-software development process; software process measurement; GQM; domain representation.

I. Introduction

In business contexts, it is of great importance that measurement practices are linked to high-level business goals in a clear and well reasoned way. A technique supporting such objectives was presented at SOFTENG 2025 [1]: it was proposed to use the GQM (Goal/Question/Metrics) technique [2]–[4]. That proposal is here extended, also with the help of a case study.

GQM has been successfully used for supporting the definition and execution of software measurement plans in a variety of industrial settings [5]–[9]. However, GQM has proven weaker in supporting the need for linking software measurement goals to higher-level goals of the organization for which the software is developed [10], [11]. Making the connection of software measurement to higher-level business goals explicit is very important for two reasons: justifying software measurement efforts and cost, and defining or using measures that effectively contribute to higher-level business-oriented decisions.

GQM+Strategies [10], [12]–[14] provides mechanisms for explicitly linking software measurement goals to business goals at different levels, up to the level of the entire business.

The scenario addressed by both GQM+strategies and this paper encompasses three elements: the business world, the measurement world, and the connections between the business and measurement worlds.

The business world (BW) is where the business operates, and includes the piece of the real world that is relevant for the business (including the market, users, stakeholders, competitors, etc.). In the BW, business goals are conceived, and strategies to achieve such goals are deployed. In most cases, strategies involve the usage of software, which very often needs to be specially developed to support a strategy. Strategies are hierarchical in nature, since implementing a strategy usually involves achieving a lower level goal, which, in turn, could require a strategy.

The measurement world (MW) is where measurement plans are specified, measures are defined, indicators (e.g., KPI) are computed. The measurement world is much more controllable than the business world. Accordingly, techniques and tools –like the GQM and related tools and methodologies– have been defined to support the work to be carried out in the measurement world.

The connections between the BW and MW represent the fact that the objects of measurement are in the business world and the data that support the evaluations performed in the measurement world are provided by the business world. Moreover, people from the two worlds need to agree on the measure definitions, how measurement is carried out, the meaning and expressiveness of indicators, etc.

GQM+Strategies highlights the relations existing between business goals and software development (or acquisition) within the BW and supports identifying and documenting the relationships between goals in the BW and measurement plans in the MW.

However, in GQM+Strategies, little attention is given to the description of the BW, with particular reference to the business goals and the strategies of interest [15]. In this respect, GQM+Strategies seems to inherit the weakness of GQM, which did not provide guidelines for modeling the relevant aspects of the software product and process that are the objects of measurement.

A clear understanding of the business domain, the rules and constraints that affect the business, the final goals of the stakeholders, and the cause-effect relationships that govern the business is of fundamental importance to devise effective strategies. Those who need to support such strategies by means of software and, then, measure the effectiveness of the software solutions and the implemented strategies, need to have access to explicit and clear descriptions of the BW. That is, they need to distinguish between what is given and cannot be changed, what is currently not true and must be achieved (the business goal), and what is the set of actions (the strategy) that have been planned to achieve the business goal.

In this paper, we propose a method to precisely describe the

BW, in terms of the business domain and its characteristics, the business goals, the strategies and their relationships with the software activities carried out to support the strategies. Then, i.e., after building an integrated and harmonic view encompassing both the business and software processes, we address the definition of business plans, using the GQM+Strategies proposal.

In other words, we believe that linking software development and business strategy is a rather complex task, so that identifying and modeling such link directly when defining measures is difficult and error-prone. Hence, we propose to first provide an integrated description of business and software processes (using the concepts of GQM+Strategies) and then to specify—via GQM plans—the measurements to be carried out. Quite noticeably, the latter activity becomes easier since the concepts of GQM+Strategies are used to describe the BW, so that identifying the business goals, the context, the strategies, etc. is straightforward.

Note that in this paper we do not propose any brand new methods for specifying business needs and software requirements. Instead, we build on existing proposals. Specifically, in addition to GQM+Strategies, we borrow ideas from Jackson's work [16]–[19] on requirements and domain representation. Thus, we are able to propose an approach that is simple and fairly easy to understand, yet powerful and applicable in practice.

The remainder of the paper is organized as follows: Section II summarizes the GQM+Strategies method and highlights the need for better models of the BW; an example originally proposed by Basili et al. [13] is also introduced. Section III proposes a (meta)model to represent the hierarchy of requirements in the BW. Section IV discusses the selection of strategies to achieve goals. Section V shows how the proposed approach can be applied to describe the BW for the example described in the Section II. Section VI discusses what to measure and describes how to links goals, strategies and the knowledge of the business world to GQM measurement plan . Related work is commented in Section VII. We conclude and we draw some directions of further investigation in Section VIII.

II. GQM+Strategies

Here, we first summarize the method as proposed by Basili et al. [10], [12], [13]. Then, we comment on the need for descriptions of the BW that are more precise and systematic than those proposed by the GQM+Strategies method.

A. A concise introduction to GQM+Strategies

GQM+Strategies aims to address the weaknesses of existing goal-oriented approaches by providing explicit links among organizational levels in a flexible manner, to tailor the approach to the organization's specific needs and objectives [12]. The proposed conceptual components are illustrated in Figure 1, taken from [12]:

- Business goals are specific organization's goals that call for software development.
- Context factors account for environmental conditions that affect both the goals and how they are pursued.
- Assumptions concern the parts of the context that are not known with certainty.
- Strategies indicate how a goal is pursued. The implementation of a strategy may involve achieving lower-level goals.
- Interpretation models indicate how to interpret data to determine if the goals at all levels have been achieved.
- A Goal+Strategies element groups the business goal, the associated strategy, and the context information and assumptions at a given level.

A single GQM goal measures a Goal+Strategies element. An example of GQM+strategies model is given in Figure 2, taken from [13]. The considered company operates in a market that is becoming highly competitive, so that there is a need to safeguard the company's place in the market, i.e., to keep the current customers. To this end, generating customer loyalty is necessary. This can be achieved by improving customer satisfaction with the next product, so business goal "increase customer satisfaction by 10%" is defined.

An analysis revealed that many customer complaints are due to product reliability problems. After considering several possible strategies, it was decided that the most promising way to increase customers' satisfaction is to "test reliability in".

In order to test reliability in, the software test processes are examined and potential lower-level goals are identified. The company has discovered a new system test process that seems appropriate for their context and that can decrease the total number of customer complaints by 10% by reducing customer-reported software field defects (i.e., those that slip by system test) by 20%. Thus, the second-level goal is to improve system test effectiveness by 20%. Because there is a new suitable system test process, the one and only strategy is to introduce the new system test process.

Based on historical defect slippage data, the company assumes that reducing slippage by 20% reduces reported defects by 20%. So, the lower level goal is to apply the new system test method in order to see if it reduces defect slippage by at least 20% and generates the necessary improvement to customer complaints.

B. On the need for better models of the Business World

The need for clarifying the BW anticipated in the Introduction can be illustrated by means of the example given in [13] and reported in Figure 2.

First, the boundaries of the BW model should be explicitly defined. Similarly, it should be clarified why some elements of the BW are in the model, while others have been excluded. In fact, given a business goal, it is always possible to wonder from where it originates, what business needs led to the definition of such goal, etc. At the opposite end, a goal that is at the ground level in a model can always call for a strategy. In fact, any goal that can be pursued in two or more different ways can be associated with a "strategy" that simply indicates which of the several possible implementation ways has been chosen.

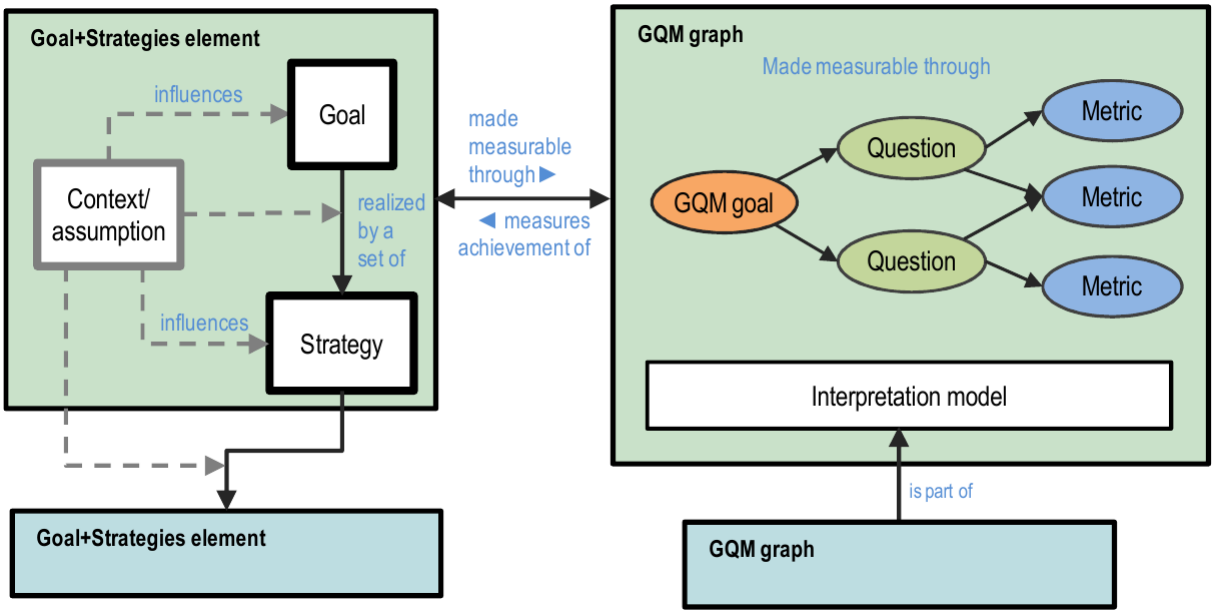

Figure 1. GQM+Strategies components [12].

Concerning the top-level goal (increasing customer satisfaction by 10%), in Figure 2, the presence of context C1 and assumption A1 suggests that such context information and the related assumptions were used to formulate the goal. However, the specific problem to which C1 and A1 were applied is not mentioned, so we do not know if there is an even higher-level goal that can be reached by pursuing the top-level goal appearing in in Figure 2. In fact, one might infer that the (unknown) higher-level business goal is increasing customers' loyalty, or just preserving the current market share, since in a competitive market, improving customers' satisfaction could be necessary not to reduce a company's market share. C1 and A1, if applied to such goal, would result in the decision of increasing customer satisfaction by 10%. In turn, this higher-level business goal may come from an even higher-level business goal (e.g., ensure the company's long-term viability). Several levels of higher-level goals may be possible.

To stop this upward chain of goals, the top-level goal should be given as an "axiom," and no context or assumptions should be provided to justify it. Otherwise, one could wonder for what specific purpose context or assumptions are applied, thus looking for a further upper level.

On the contrary, at the bottom level, the basic strategy should be either sufficiently simple to require no further refinement and it should be measurable, as any strategy in the GQM+Strategies approach.

Another fundamental observation is that several different strategies can possibly satisfy a given business goal. For instance, customers' satisfaction can be increased in several different manners: increasing the reliability of products is surely a way, but it could be possible to decrease prices, to add functions, to improve efficiency, etc. The criteria for choosing a strategy over others are not given in Figure 2. This is a rather severe limit of the BW modeling in GQM+Strategies. In some cases, strategies could be constrained by the context (e.g., decreasing the price of the product could just be impossible), but strategies more often derive from the preferences and the knowledge (obtained via market analysis and the like) of the people in charge of decisions. In such cases, explicitly recording the decision criteria that lead to selecting a strategy would be beneficial, since decision criteria could play a very important role in the evaluation of strategies.

In the considered case, suppose that two possible strategies were viable: a) give discounts to customers; b) increase customers' support. Suppose also that option b) was chosen because it was considered less expensive for the company. This decision can be carried out based for instance on market data and simulations (a sort of "what if" analysis) for both strategies. Thus, if all this were documented, we could evaluate if the strategy selection criterion is sound, according to the knowledge and models available before choosing strategy b). After the selected strategy is executed, we could verify whether the criterion worked as expected, i.e., if customer loyalty increased when increasing customer support. In any case, since we have already evaluated what would have happened if we had chosen strategy a), according to available data, we can compare the actual results obtained with strategy b) and the predicted results with strategy a). In any case, the criterion "a) costs more than b)" would be explicit and verifiable. Over time, by recording the decisions made, their rationales, and the results obtained, we can reach a reliable evaluation of the strategy selection criterion that can be recorded (e.g., in the Experience Factory [20]) as an asset for the organization for future use.

A further observation is that the connections between strategies and the corresponding sub-goals in Figure 2 are not all well defined. For instance, reducing defect slippage must

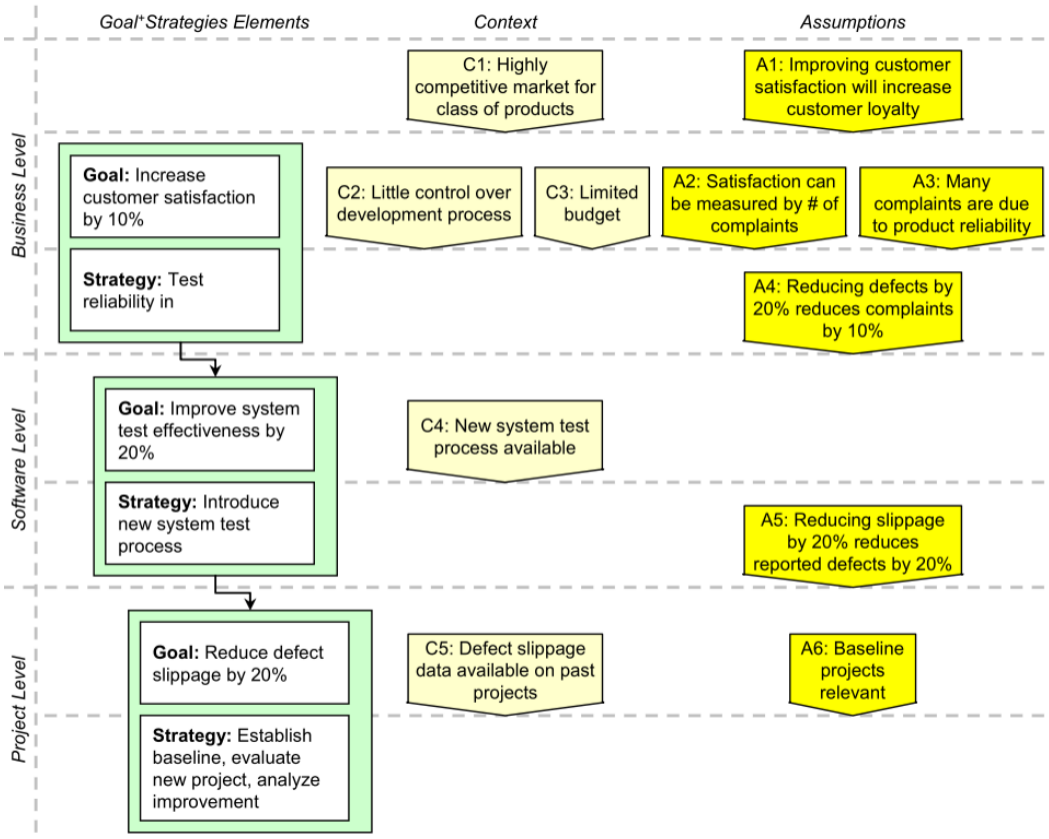

Figure 2. Goals, strategies, context factors and assumptions [13].

be a property of the new system test process addressed by the software-level strategy. In fact, "introducing a new system test process" is not a reasonable strategy by itself, since the new process could be worse than the existing one. An effective strategy consists in "introducing a new system test process that reduces defect slippage by 20%." The origin of the confusion here is probably that in this case the project-level goal could be identical to the software-level strategy. In other words, to implement a strategy that requires a new system test process that reduces defect slippage by 20% what is needed is just a project whose goal is to introduce a new system test process that reduces defect slippage by 20%. The fact that a strategy at a given level becomes a goal as-is at the immediately lower level should not be surprising. Finally, it should be noted that implementing a given strategy could require multiple sub-goals. For instance, a Strategy could require achieving sub-goals both on the technical side (e.g., introducing tools, platforms, etc.) and on the competence side (e.g., acquire some skill or knowledge). This situation—not shown in Figure 2—is quite common in practice.

III. Requirements Hierarchies

Some work has been done in the area of representing the hierarchies of requirements ranging from high-level business requirements to software development requirements. Some of the existing proposals also address the precise (possibly formal) description of the requirements and the domains in which they exist.

We here propose a (meta)model for representing in a quite systematic and rigorous way the hierarchy of requirements in the BW and (in the next section) their links to the measurement plans.

A. Describing requirements: Jackson's method

In this paper, we use the concepts for requirements specification proposed by Jackson [16]–[19].

Jackson noted that the relationship between user requirements and the specifications of a hardware/software machine that has to satisfy such requirements in a given environment can be described as follows [21]:

$$E, S \vdash R \tag{1}$$

In (1), R indicates the stakeholder's requirements, i.e., "conditions over the phenomena of the environment that we wish to make true by installing the machine" while E expresses "conditions over the phenomena of the environment that we know to be true irrespective of the properties and behaviour of the machine" [17]. S is the specification of the machine, expressed in terms of the phenomena that are shared by the environment and the machine. In practice, S is specified in terms of I/O elements: in Jackson's terminology, phenomena controlled by the environment and visible to the machine (i.e.,

inputs) and phenomena controlled by the machine and visible to the environment (i.e., outputs).

Formula (1) states that if the environment in which the machine is located behaves as specified in E and the specifications S are satisfied by the machine and the environment, then requirements R are satisfied. The logical entailment $A \vdash B$ states that from assuming A we can prove B; hence, entailment is often called provability. It is important to note that the level of formality of formula (1) depends on the formality of the descriptions E, S and R. If E, R and S are described formally it is possible to prove that the truth of R descends from the truth of E and S, while informal descriptions allow only for argumentations, which are deemed sufficient in most case, though.

B. Describing requirements hierarchies

Given a context and a goal, the strategy is the "solution" that—in the given context and under the given assumptions—satisfies the goal.

Using Jackson's concepts and notation, the statement above can be written as follows.

$$Context, Strategy \vdash Goal$$

where Context is the description of the business domain, including all the knowledge that is relevant with respect to the goals currently considered, Goal is the description of what is desired by the business actors, and Strategy is the solution that has been devised to achieve the goal.

In Jackson's terminology, the context is given, thus it is "indicative." More precisely, in GQM+Strategies [12], the context includes:

- Factors (known with certainty);
- Assumptions (uncertain).

Accordingly, we could say that

$$Context_F, Context_A, Strategy \vdash Goal$$

where $Context_F$ is the description of the factors known with certainty and $Context_A$ is the description of the assumptions. It could be observed that also part of the context can be controlled or changed: for instance, the employees working in the considered environment can be instructed to behave in a given way, devices can be installed, etc.. Thus, this part of the context is not really indicative, since changing it could actually be part of a strategy.

The Goal is "optative," i.e., it represents something that is not currently true, but needs to be made true. In fact, the application of the Strategy in the Context is the means by which the Goal is satisfied.

The Strategy is clearly optative, since in general the Goal can be achieved via several different strategies. More precisely, the initial situation can generally be represented as follows:

$$Context, ? \vdash Goal$$

In this formula, the question mark explicitly indicates that in a given (known) context there is a goal (i.e., some desirable conditions currently not holding), but how to achieve it is yet to be defined.

Once the Strategy has been described, i.e., we have decided what has to be achieved, it is necessary to specify how it should be achieved. This is why goals and strategies form hierarchies (as in Figure 1): implementing a strategy in general requires the achievement of some lower-level goal. For this purpose, a lower-level strategy is required, which could require the achievement of an even lower-level goal, etc. This type of requirements hierarchies is described in [22], using Jackson's notation.

$$Context, Strategy \vdash BusinessGoal$$
$$Context, LowerLevelGoal \vdash Strategy$$
$$Context, LowerLevelStrategy \vdash LowerLevelGoal$$

The LowerLevelGoal specifies what we can do to realize the Strategy: reaching LowerLevelGoal in the Context is a sufficient condition for the realization of the Strategy. However, LowerLevelGoal is itself a goal, so it is also necessary to specify how the LowerLevelGoal should be achieved. To this end, we need to devise a LowerLevelStrategy to reach LowerLevelGoal as shown in the last logical entailment above.

IV. Selecting a Strategy

Different strategies are characterized by different costs, effectiveness, risks, and benefits, so that choosing a strategy (i.e., exercising the option) implies that multiple characteristics of multiple strategies may need to be assessed. Therefore, in addition to the Goal, a Figure of Merit (FM) exists, whose value depends on the Context and the Strategy. The FM can be used in two ways. First, a constraint can be set on the FM. For instance, if cost is the FM, we can consider acceptable only strategies whose cost is below a specified cost threshold. Second, the FM can be used to comparatively assess different strategies, based on a Preference Criterion (PC) that ranks alternatives based on their corresponding values of FM. The PC may be a straightforward one when the FM is a single-objective one. However, FMs are often multiple-objective: for instance, a double-objective FM may address effort and development time. The application of the PC results in general in a partially ordered set of strategies, as some strategies may be deemed equivalent as for their FMs.

Making the FM and PC explicit shows that the selection of a strategy is not based only on the Goal; instead, it involves the optimization of characteristics that do not necessarily appear in the Goal. For instance, take the business Goal in the example, which should be interpreted as "Increase customer satisfaction by at least 20%." This Goal sets a constraint on the set of possible strategies used to reach it, but by no means does it explicitly indicate how to choose among competing strategies that satisfy it. In principle, one could choose any Strategy that satisfies the Business Level Goal in the given Context, regardless of the cost. However, in practice, the Strategy that minimizes the cost is likely to be preferred over the others.

Also, making the FM and the PC explicit provides guidance in the building of effective strategies, when no previously used strategies are available, or in the tailoring of existing ones or when there is a significant level of uncertainty, which is always present when making decisions. If so, we may not be able to identify the optimal Strategy with certainty, but the FM and the PC will help us at least reduce the set of strategies.

Summarizing, the FM and the PC need to be made explicit so that all ambiguities are removed as to why a specific Strategy is selected. Also, the analysis of the results obtained in the field will allow us to refine our decision processes.

V. Describing the Business World

To illustrate the notation described in Section III, in this section, we describe the example illustrated in Figure 1 using the proposed notation. In describing the business world and how to cope with the given high-level goal, we also show how to solve the problems with the GQM+Strategies descriptive power discussed in Section II.

The high-level objective is *"Preserve market share."* This objective is given and is not under discussion. It serves as an axiom for the following reasoning.

Having the goal, we have to decide how to pursue it, i.e., we have to define a strategy that (hopefully) will let us achieve the goal. To define the strategy, we consider the following knowledge of the business world:

High competitive markets, User satisfaction not high $\vdash$
Loss of market share

Since the market competitiveness is out of our control, to avoid losing market share we have to achieve high customer satisfaction. In other words, we adopt a strategy consisting in improving user satisfaction. Note that loss of market shares could be caused also by other factors than user satisfaction, but these other factors are not considered in this example.

So, *Improving user satisfaction* is a new goal. Again, we have to devise a strategy to achieve this goal. To such end, we can exploit the knowledge that satisfaction depends on reliability (the more reliable is a product, the more satisfied is the customer), as stated by the following entailment:

Increased product reliability $\vdash$ *Improved customer satisfaction*

So, increasing product reliability (i.e., *Reducing defects* in the released product) is our new goal. To pursue this objective, we exploit the knowledge that effective tests decrease defects.

Effective testing $\vdash$ *Low defect rate*

So, the new objective is *Increase test effectiveness*. To pursue this objective, we exploit the knowledge that

New system test process available,
New system test process usage $\vdash$ *Increased test effectiveness*

Therefore, adopting the new system test process is the chosen strategy. We can suppose that the adoption of the new system test process is a "ground activity" that does not need to be further discussed. Otherwise, we could proceed as above, by considering what is needed to introduce the new system test approach in the current development process, etc.

Note that the description above is coherent with the GQM+Strategy definition. This is evident from Figure 3, which describes a fragment of the requirements hierarchy as a GQM+Strategy element: its can be observed that the Goal, Strategy and Context/assumptions are described via the proposed notation borrowed from Jackson.

Now, a quite important point with the proposed notation is that Jackson does not prescribe how to specify individual statements. For instance, *"Improving user satisfaction"* could be specified in plain English or by means of some type of temporal logic. Quite interestingly, the same happens with GQM, where the processes or products that are object of measurement can be described in any possible way.

We maintain the approach of Jackson and GQM, and do not suggest any specific notation: each practitioner is free to adopt the notation he/she is most familiar with.

Other important observations are the following.

As already mentioned, given a strategy, we have to specify how the strategy is carried out. That is, we need to define a lower level goal that represents the implementation of the strategy. While the GQM+strategies method is not very clear on this point, with our approach the procedure is quite straightforward: the relationship between Strategy and sub-goals is the same as between Goal and Strategy.

It can be noticed that in formula $Context, Strategy \vdash BusinessGoal$ the Strategy is optative, i.e., we are free to choose one among the possibly multiple strategies that support the achievement of the goal. On the contrary, in formula $Context, LowerLevelGoal \vdash Strategy$, the strategy has become indicative, while the lower level goal is optative, since there are potentially multiple ways to implement the strategy: for instance, *Improved customer satisfaction* could be the consequence of other factors than *Increased product reliability*. These observations are coherent with the fact that proceeding from the business goal level to the operational goals at the lowest level involves a sequence of decisions. The description method we propose is suitable to represent the progress of the decisional process as well as the cause-effect relationships that link goals and strategies at the different levels.

Another important observation is that formulae like

Effective testing $\vdash$ *Low defect rate*

can be written at different levels of detail. For instance, we could distinguish different types of defects. Also in this case, the proposed method can be used at the level of detail considered suitable by the user: e.g., one could specify what "effective test" means and what are the expected effects on the different types of defects.

A final consideration is that Basili et al. suggest three levels, namely Business, Software and Project [12], while we do not limit the number and type of levels.

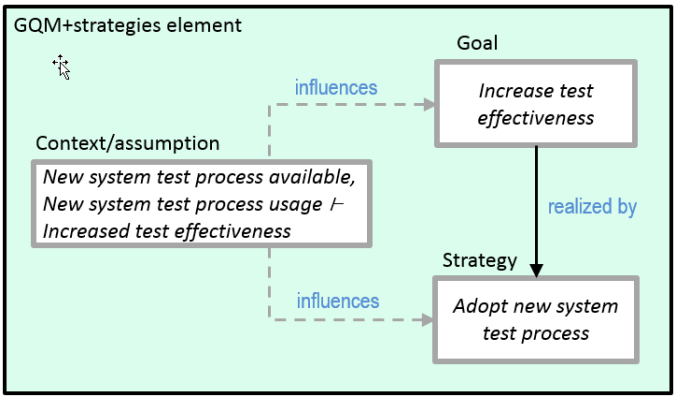

Figure 3. A GQM+Strategy element from the case study.

VI. What Should Be Measured (and How)

Basili et al. provide the following indications for measurement [12]:

> *Associated with each GQM+Strategies element is a measurement plan that uses the GQM measurement and evaluation framework to specify how to evaluate the goal, what data to collect, and how to interpret that data. The nodes of each GQM graph consist of a measurement goal, which describes what knowledge needs to be gained from the measurement activity; a set of questions to be answered; the metrics and data items required to answer the questions; and an interpretation model that specifies how the data items are to be combined and what the criteria are for determining the goal's success.*

With respect to the situation described in Figure 1, formula

$$Context, Strategy \vdash Goal$$

provides clearer indications about what should be measured. In fact, while in [12] a single GQM plan is connected to a Goal+Strategy element, our method naturally suggests specific measurement plans for each part of the entailment:

- Context: if the context description contains assumptions, it is generally a good practice to measure to what extent the assumptions are true.
- Goal: of course, we want to know to what extent the goal has been achieved. To this end, a GQM plan is typically attached to the business goal.
- Strategy: we want to know to what extent and how well the strategy has been applied. So, a specific GQM plan is typically defined for the strategy.

For sure, we want to measure the Figure of Merit associated to a given entailment. In some cases, we could even have multiple Figures of Merit, each one representing a specific point of view. For instance, we could have a Figure of Merit for top management and another one for the project manager. Measuring the Figure(s) of Merit usually requires measuring the elements (the Context, the Strategy and possibly the Goal) to which a Figure of Merit refers. However, it must be noted that very often a Figure of Merit concerns properties (e.g., the amount of resources used to implement a Strategy, or the time taken to complete the activities involved in a given Strategy) that belong to a sort of meta-level, and are possibly not considered in the "basic" measurement of Strategy. The quantification of Strategy selection criteria usually does not call for additional measures, instead it is just a function of the computed Figure(s) of Merit.

As an example, let us consider the entailment *New system test process usage* $\vdash$ *Increased test effectiveness* from Section III: evaluating the Figure of Merit involves measuring properties like the cost of testing, the increase of competence needed to conceive tests, the cost and the learning curve of tools and practices used for testing, etc.

The entailment is usually assumed to be true. In other words, it is believed that the devised Strategy, correctly applied in the given Context, causes the full achievement of the Goal. However, it may happen that the Goal does not follow from the Context and Strategy: measuring also this fact is therefore advisable. This usually involves verifying the connections between properties of the processes and products addressed by the Strategy and processes and products considered in the Goal. For instance, one of the conditions that make the entailment *Effective testing* $\vdash$ *Low defect rate* true is that the results of testing are fed to an effective debugging activity.

The interpretation model mentioned in [12] is clearly of great importance, since the whole interpretation of the collected data depends on it. Nevertheless, in [12] it is not specified how the interpretation model should be defined, it being delegated as part of the GQM plan. This is not advisable, in that the GQM itself is generally more oriented to refining goals into metrics than in prescribing how the collected data would be interpreted.

With our approach, the interpretations are generally made apparent by the formulae. Moreover, we do not have multiple GQM plans and graphs, as in Figure 1; instead we have a single plan, with clearly interconnected elements, as shown in Figure 4 (which schematically represents a portion of the requirements hierarchy).

The connections between a strategy and its lower level goals

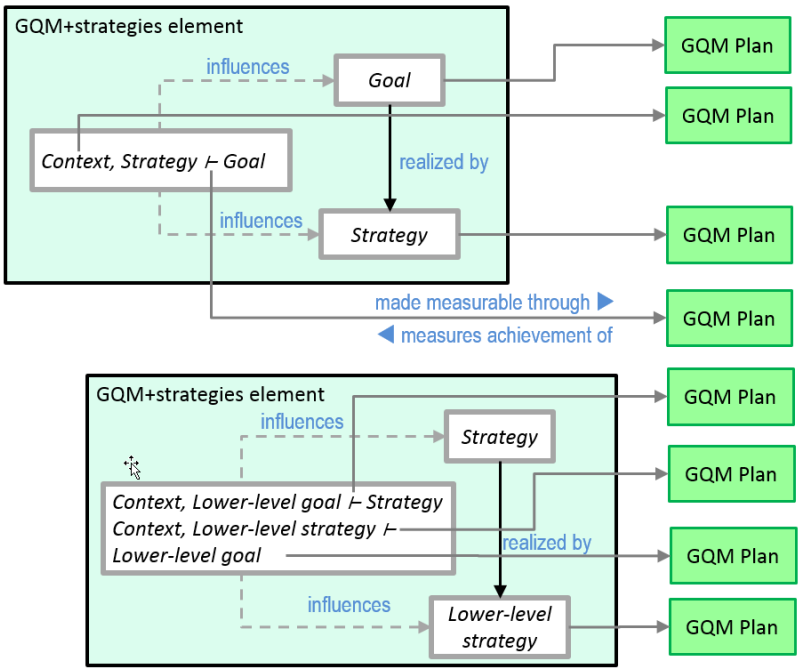

Figure 4. Our proposal for measurement.

are not emphasized by Basili et al., while they are clearly represented and measured in our approach.

Figure 5 illustrates the connection of GQM+Strategy elements to GQM plans with our approach: it can be observed that every component of the considered GQM+Strategy element, i.e, every goal, strategy, entailment, etc., is connected to one or more GQM plans. In this way, the definition of GQM plans is straightforward.

VII. Related Work

The weakness of GQM in describing the software product or process that is the object of measurement were overcome by coupling GQM-compliant measurement tools with tools for modeling the product and process [23]. The work described here can be seen as a logical prosecution of that work, in that here we provide the basis for coupling reasoning on business goals, user requirements, software development and –finally– measurement.

The need for linking business processes and Goal/Question/Metric paradigms has been felt since 2004 [24]. In [24] the authors define a measurement framework to support process analysts in assessing business processes by means of the GQM paradigm, to find useful indications about process performance, critical elements, change impact, and expected improvement. In our approach, the focus moves from a way to assess the quantitative and qualitative aspects of a business process to a way to precisely (possibly formally) describe business processes in a manner that is compliant with the GQM paradigm. The precise description of the business world and of company goals eases both the measurement of process aspects and the evaluation—both quantitative and qualitative—of the business and technical aspects of the process.

GQM+Strategies has been introduced for the first time in [10] to extend the GQM approach with the capability to create measurement programs that ensure a link between business goals and strategies, software goals, and measurement goals. The approach has been supported by the SAS tool to improve the definition of the context, assumption, and strategies [25]. In our paper, we adopt the extensions proposed in [10] to go further in the direction of representing the BW processes that are to be connected with GQM+Strategies. Our approach makes the representation of relevant relationships explicit, independently from the GQM.

In [26], the GQM+Strategies approach is adopted to perform business value analysis and to identify success/critical business goals. The paper clearly states that the various aspects of business value expressed and defined by goals require the knowledge and experience of the stakeholders to identify what elements (context, assumptions, strategies, goals) are valuable and appropriate for the company's success. In our paper, we aim at improving the process of describing the BW, in terms of the business domain, characteristics, goals, strategies and relationships with the software activities.

In [15], the author notes that the business level should be mapped into a Conceptual/Strategic level to clearly define the scope of the Business level in a generic way (i.e., outside the boundary of the software domain): the conceptual level is actually the highest organizational abstraction where an organization determines how to succeed in those activities that are strategic for the existence of the organization itself. This kind of mapping is quite easy with our approach.

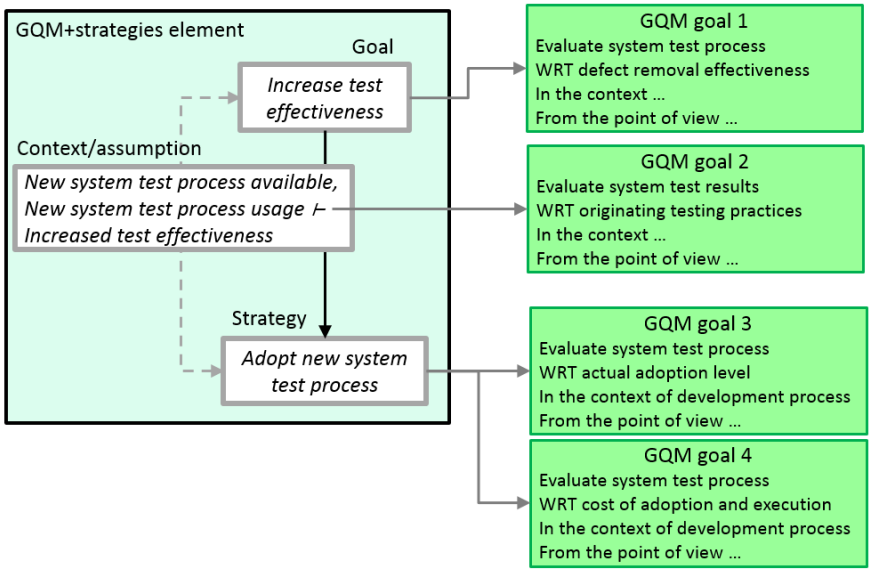

Figure 5. Linking GQM plans to GQM+strategy element components.

VIII. Conclusions and Future Work

In this paper, we propose a method to better link the GQM+Strategies methodology with the business goals of an organization. Our proposal is based on using Jackson's ideas on domain representation, and allows for the precise description of the business domain, the business goals, the strategies, and their relationships with the software activities carried out supporting the strategies, and how strategies are selected.

Thus, the proposal of this paper does not consist in inventing a new technique or notation, but in using two existing techniques to make their joint use applicable in practice. The proposal also makes it possible to clearly and explicitly describe and therefore record the rationale behind the selection of strategies. A Figure of Merit (in addition to a Goal) of practical interest needs to exist for the evaluation of strategies in a given Context. A Preference Criterion must be defined so the different strategies can be ranked according to the values of their Figure of Merit. The approach proposed in this paper has been demonstrated by using it on a case proposed in the literature on GQM+strategies.

The proposed technique is meant to describe buiness environments and strategies, in relation with software activities and software artifacts. As such, it can be used in multiple context and for multiple objectives. For instance, the proposed tecnique is suitable to support process improvement initiatives, irrespective of the adopted framework (e.g., CMMI, ISO standards, etc.)

A significant amount of future work remains do be done, including applying the approach to larger application cases and developing supporting tools to be integrated with existing GQM tools [23], [27]–[30].

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References

[1] L. Lavazza, S. Morasca, and D. Tosi, "Putting business goals in context for measurement", in *SOFTENG 2025 : The Eleventh International Conference on Advances and Trends in Software Engineering*, 2025, pp. 8–13.

[2] V. R. Basili and H. D. Rombach, "The TAME project: Towards improvement-oriented software environments", *IEEE Transactions on Software Engineering*, vol. 14, no. 6, pp. 758–773, 1988.

[3] V. R. Basili and D. M. Weiss, "A methodology for collecting valid software engineering data", *IEEE Transactions on Software Engineering*, no. 6, pp. 728–738, 1984.

[4] V. R. Basili, G. Caldiera, V. R. Basili, and H. D. Rombach, "Goal question metric paradigm", *Encyclopedia of Software Engineering*, vol. 1, no. 528-532, p. 6, 1994.

[5] A. Fuggetta *et al.*, "Applying GQM in an industrial software factory", *ACM Transactions on Software Engineering and Methodology (TOSEM)*, vol. 7, no. 4, pp. 411–448, 1998.

[6] A. Birk, R. Van Solingen, and J. Jarvinen, "Business impact, benefit, and cost of applying GQM in industry: an in-depth, long-term investigation at Schlumberger RPS", in *Proceedings Fifth International Software Metrics Symposium. Metrics (Cat. No. 98TB100262)*, IEEE, 1998, pp. 93–96.

[7] R. Van Solingen and E. Berghout, "Integrating goal-oriented measurement in industrial software engineering: industrial experiences with and additions to the Goal/Question/Metric method (GQM)", in *Proceedings Seventh International Software Metrics Symposium*, IEEE, 2001, pp. 246–258.

[8] L. Lavazza, "Multi-scope evaluation of public administration initiatives in process automation", in *The European Conference on Information Systems Management*, Academic Conferences International Limited, 2011, p. 294.

[9] L. Lavazza and M. Mauri, "Software process measurement in the real world: Dealing with operating constraints", in *Software Process Change: International Software Process Workshop and International Workshop on Software Process Simulation and Modeling, SPW/ProSim 2006, Shanghai, China, May 20-21, 2006. Proceedings*, Springer, 2006, pp. 80–87.

[10] V. Basili *et al.*, "GQM+strategies—aligning business strategies with software measurement", in *First International Symposium*

on Empirical Software Engineering and Measurement (ESEM 2007), IEEE, 2007, pp. 488–490.

[11] L. C. Briand, S. Morasca, and V. R. Basili, "An operational process for goal-driven definition of measures", *IEEE Transactions on Software Engineering*, vol. 28, no. 12, pp. 1106–1125, 2002.

[12] V. R. Basili *et al.*, "Linking software development and business strategy through measurement", *Computer*, vol. 43, no. 4, pp. 57–65, 2010.

[13] V. Basili *et al.*, "Determining the impact of business strategies using principles from goal-oriented measurement", in *Business Services: Konzepte, Technologien, Anwendungen. 9. Internationale Tagung Wirtschaftsinformatik*, Osterreichische Computer Gesellschaft, 2009.

[14] V. Mandić, L. Harjumaa, J. Markkula, and M. Oivo, "Early empirical assessment of the practical value of GQM+ Strategies", in *New Modeling Concepts for Today's Software Processes: International Conference on Software Process, ICSP 2010, Paderborn, Germany, July 8-9, 2010. Proceedings*, Springer, 2010, pp. 14–25.

[15] S. A. Sarcia', "Is GQM+Strategies really applicable as is to non-software development domains?", in *Proceedings of the 2010 ACM-IEEE International Symposium on Empirical Software Engineering and Measurement*, 2010, pp. 1–4.

[16] C. A. Gunter, E. L. Gunter, M. Jackson, and P. Zave, "A reference model for requirements and specifications", *IEEE Software*, vol. 17, no. 3, pp. 37–43, 2000.

[17] M. Jackson, "The meaning of requirements", *Annals of Software Engineering*, vol. 3, no. 1, pp. 5–21, 1997.

[18] M. Jackson, *Problem Frames: Analyzing and structuring software development problems*. Addison-Wesley Longman Publishing Co., Inc., 2000.

[19] M. Jackson and P. Zave, "Deriving specifications from requirements: An example", in *Proceedings of the 17th International Conference on Software Engineering*, 1995, pp. 15–24.

[20] G. Caldiera, V. R. Basili, and H. D. Rombach, "The experience factory", *Encyclopedia of Software Engineering*, vol. 1, pp. 469–476, 1994.

[21] M. Jackson, "Software specifications and requirements: A lexicon of practice, principles and prejudices", *Addison-Wesley, New York*, 1995.

[22] L. Lavazza, "Business goals, user needs, and requirements: A problem frame-based view", *Expert Systems*, vol. 30, no. 3, pp. 215–232, 2013.

[23] L. Lavazza and G. Barresi, "Automated support for process-aware definition and execution of measurement plans", in *Proceedings of the 27th International Conference on Software Engineering*, 2005, pp. 234–243.

[24] L. Aversano, T. Bodhuin, G. Canfora, and M. Tortorella, "A framework for measuring business processes based on GQM", in *37th Annual Hawaii International Conference on System Sciences, 2004. Proceedings of the*, IEEE, 2004, 10–pp.

[25] V. Mandić and M. Oivo, "SAS: A tool for the GQM+strategies grid derivation process", in *Product-Focused Software Process Improvement: 11th International Conference, PROFES 2010, Limerick, Ireland, June 21-23, 2010. Proceedings 11*, Springer, 2010, pp. 291–305.

[26] V. Mandić, V. Basili, L. Harjumaa, M. Oivo, and J. Markkula, "Utilizing GQM+Strategies for business value analysis: An approach for evaluating business goals", in *Proceedings of the 2010 ACM-IEEE International Symposium on Empirical Software Engineering and Measurement*, 2010, pp. 1–10.

[27] C. Lofi, "Continuous GQM", Ph.D. dissertation, Master's thesis, Technical University Kaiserslautern, Germany, 2005.

[28] M. Hoffmann, A. Birk, F. van Els, and R. Kempkens, *GQM aspect v1.0 User manual*, 1996.

[29] J. C. Abib and T. G. Kirner, "A GQM-based tool to support the development of software quality measurement plans", *ACM SIGSOFT Software Engineering Notes*, vol. 24, no. 4, pp. 75–80, 1999.

[30] P. Parviainen, J. Jarvinen, and T. Sandelin, "Practical experiences of tool support in a GQM-based measurement programme", *Software Quality Journal*, vol. 6, pp. 283–294, 1997.