Assessment of Performance in the Domain of Product Development

by
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B.S. Electrical and Electronics Engineering
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Abstract

Improvement of business performance is an enduring subject of research across a diverse set of disciplines such as accounting, operations management, marketing, finance, economics and even psychology and sociology. In any discipline the ability to create self-awareness, a capacity to evaluate and compare their own behavior to internal standards and values, is a pre-requisite of improvement. In an organization, self-awareness is created with assessments. The results of assessments can help the organization to adapt to changing market conditions by defining more valuable objectives to direct its new businesses as well as to restructure its operations for eliminating deficiencies that limit its abilities to achieve its business goals at lower costs. For an organization with core businesses in product development (PD), assessment of PD is an essential element of all business improvement initiatives. However, in order to perform a focused PD assessment, the analysis needs to be structured with a systematic top-down approach which relates the findings of evaluations starting from high-level business goals down to the metrics for the most detailed operational activities. In this

thesis, an existing Product Development Self-Assessment tool is integrated into this context, and implementation of a top-down assessment is presented using a three-step process. Other supplemental tools and methods are also incorporated into the discussion of the implementation framework such as; Goal-Question-Metric (GQM) and IDEF0 function modeling methodologies. With the use of illustrative examples, the application steps of the framework and the use of supplemental methods are presented.

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I had the opportunity to finalize my thesis in a small village on the Mediterranean coast, where my MIT journey started when I sent my application forms to MIT System Design and Management Program. In these two years, I learned more than I expected. I would like to thank the whole SDM staff and my colleagues for sharing their knowledge and wisdom with me.

I am also very lucky to be a part of MIT Lean Advancement Initiative (LAI) during my studies at MIT. With the inspiration that I inherited from the LAI family, applying lean principles in organizations will be one of my most persistent aspirations.

Dr. Eric Rebentisch was more than an advisor for me. With his mentorship, I understood the principles of doing research and shaped my own answers for my research questions. His support and guidance will extend beyond this work and will help me in my future studies.

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1 Introduction

1.1 Motivation

Self-awareness is an indication of intelligence for entities, which have capacity to evaluate and compare their own behavior to internal standards and values. This property is very critical for adaptation to changing environments, as well as for being able to improve. However, "improvement" is one of the most ambiguous words in language. In order to convey a meaningful concept, this word requires additional information such as; an understanding of "the criteria for doing well"," a method to compare the value two different states of an entity", and "a method to make the tradeoff between cost and benefit of improvement". For business entities, self-awareness starts with the capability of self-assessment, which sets the standards and criteria for doing well in business activities. However, in order to be able to act on the findings of an assessment, and select the right interventions for improvement, the issues addressed by the assessment need to be decomposed into actionable and measurable issues. A notional representation of an "improvement process" has been outlined in Figure 1.

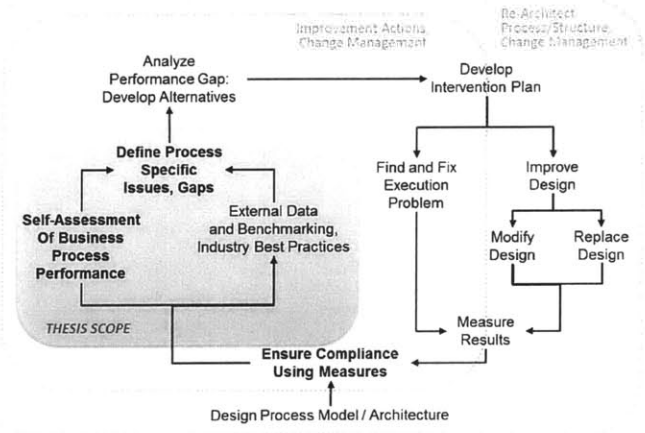

Figure 1 Notional Representation for the Business Process Improvement (Hammer, 2010)

Change management, development of intervention plans, activities about fixing the problems or architecting a new process architecture (the notional representation of their relations is given in Figure 1) are beyond the scope of this work. This work focuses on methods for identifying gaps and their related metrics by using a three-step process which is analogous to the flow of a typical improvement cycle in the organization. These steps are as follows:

- Business level assessments
- Defining specific issues and gaps related to core operations of the organization (e.g. product development)
- Defining the process-specific metrics that can be used to make decisions about required interventions and to monitor the results of interventions

In literature, there is a substantial amount of theoretical knowledge about assessment approaches that can be used for each of these steps. These approaches are mostly confined in one domain; such as 'business performance assessments', 'product development assessments', 'process quality assessments'. However, the value of insights obtained from assessments can be increased and the analysis effort can be kept more focused with the integration of these steps. Capturing this additional value with the use of an integrated assessment framework is the core motivation of this thesis.

1.2 Thesis Goal

This thesis shares similar goals with some of the fundamental studies introduced in 1990s where the need for "integrating high-level business performance indicators with operational level measures" was identified and frameworks such as "Balanced Scorecard (BSC)" (R. S Kaplan & Norton, 1992), "Smart Pyramid" (Cross & Lynch, 1988) and "Performance Prism" (A. Neely, Adams, & Crowe, 2001) were introduced. One common approach for these studies was suggesting a method to connect macro parameters of success of a business with the micro level metrics and keep operations aligned with strategic goals. This required looking at different performance measures which are linked to one another at different levels and were "collectively exhaustive" (McKinsey MECE Principle: Rasiel, 1999) in addressing the problems of a business and identifying performance gaps. An approach to 'classify' and 'relate' such measures at different levels in a systematic way has potential to improve the effectiveness of diagnosing business problems and improving the overall performance of the organization. Therefore, the goal of this thesis is to be able to present a methodology to link high-level assessment results to case specific diagnosis of business operations and metrics with a systematic approach.

In the domain of business level analysis, there is profound knowledge and very established frameworks such as Balanced Scorecard (R. S Kaplan & Norton, 1992) and BPMM (OMG, 2008). Organizations can use these frameworks to identify the high-level gaps in their business processes. Once, these improvement areas (gaps) have been identified, they need to be decomposed into specific issues and relate to corresponding metrics to investigate the problem; which requires integrating different approaches, also serving as the goal of this thesis.

This work also has aspirations in remedying the challenges of improvement initiatives in an existing organization. The organization is a large global firm with core strengths in technology and product development. Corporate-level consulting units within this firm have the responsibity for improvement of product development activities, and use a number of different of assessments to identify potential improvement areas within local business units (e.g. CMMI (SEI, 2010)). However, due to the specific practices and activities of business units, resolving high-level issues by breaking them down into actionable pieces has been a challenge for the organization. The practical goal of this work is to develop an integrated process, which can be used by corporate-level consulting units to assist them in identifying possible improvement areas in a comprehensive way, and yet include enough details to diagnose issues in a quantifiable manner with corresponding measures and metrics.

1.3 Thesis Organization

The work is divided into four chapters. Chapter 1 serves as an introduction to the body of work and outlines the motives and objectives of this work. The structure of Chapter 2 and Chapter 3 is aligned with the flow of a typical improvement cycle, which was introduced in section 1.1. This structure is shown below.

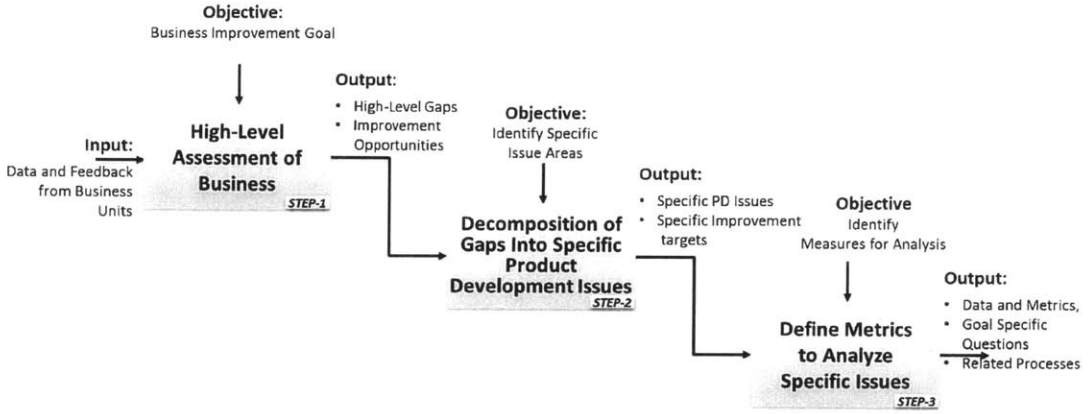

Figure 2 Flow of a typical improvement cycle

Introduction of the material in Chapter-2 and Chapter-3 follows the steps defined in the above figure. However, in order to emphasize the correlation of the thesis content with this structure, the alignment of steps and specific sections within these chapters is presented in the table below:

Corresponding Step for Improvement Initiative	Chapter-2 Theoretical Background	Chapter-3 Presentation of Framework
Step-1. High-Level Assessment of Business	***Section 2.1.*** Assessment of Business Performance	***Section 3.1.*** High-Level Assessment of Business
Step-2.Decomposition of Gaps into Specific Product Development Issues	***Section 2.2.*** Assessment of Product Development	***Section 3.2.*** Questionnaire for Product Development Assessment

Corresponding Step for Improvement Initiative	Chapter-2 Theoretical Background	Chapter-3 Presentation of Framework
Step-3. Define Metrics to Analyze Specific Issues	***Section 2.3.*** Measurement and Goal Driven Assessment	***Section 3.3.*** Defining Metrics for Case-Specific Diagnosis of Issues
Supporting material for use within different steps	***Supporting Section 2.4.*** Process Centric View of Business Performance	Used in various representations within Chapter 3.
	Supporting Section 2.5. IDEF-0 Model for Process Modeling	

Table 1 Mapping of Thesis Sections to Improvement Steps

In order to introduce the discussion in each section, a brief summary will be presented in the following paragraphs.

Chapter 2 introduces basic terms and investigates the state-of-the-art in business performance management. In this context, three important performance management frameworks are introduced. These frameworks provide insight about what aspects need to be questioned in an assessment. The perspectives of these frameworks (Section 2.1) are independent of the main activity of the business. We use them as a starting point in looking at a business. We also analyze the content of our product development assessment questionnaire (Section 2.2) to see the coverage of the questionnaire, and distribution of questions on the business dimensions introduced by these frameworks. Section 2.3 introduces a different approach; "goal-based measurements". The simplest rationale for including this perspective can be summarized as follows; "an assessment without a goal is not likely to guide the assessors to focus on the correct metrics" to diagnose the issues. Goal-Question-Metric (GQM) methodology strongly relies on the traceability of "improvement goals" down to "measures that identify the situation in terms of current state".

In section 2.4. we will divert to a "process centric" view of performance and attempt to complement the "strategy" and "alignment" focused approaches of previous sections. Currently, there is a strong opinion in industry which asserts that successful business result is an outcome of high-performing processes. In this section, we will review the significant works of some authors that will help us visualize how process view helps in seeing business as a network of activities that connect strategies with operations and depicting interactions of different activities within the organization. In this section, we will also explore the origins of terms such as "efficiency" and "effectiveness", which are fundamental in expressing performance of processes. As an original contribution, we will add "goal setting performance" to the existing picture and integrate this aspect to the process view as the third performance dimension supporting "effectiveness" and "efficiency".

During the assessment process, the assessor needs to have a picture of how the business operates and be aware of the dependencies between different processes. This awareness will help the assessor in defining the correct boundary of assessment and stay focused on the activities relevant to the goals of the assessment. As a flexible and strong candidate for structuring this activity network, we use the IDEF0 methodology. In this work, IDEF0 is suggested as a supporting method to help the assessor in depicting the complex interactions between different activities at different levels of the organization if such representations do not already exist. In addition to suggesting use of IDEF0 as a process modeling tool, we will attempt to integrate the 3 performance dimensions (goal setting, effectiveness, efficiency) in the representation. This 3 dimensional view is expected to introduce new questions about looking at process performance issues, where the classical views are mostly biased toward remedying efficiency issues or focused on effectiveness of management, and questioning the value of the original "goals" is mostly omitted.

In Chapter 3, we attempt to integrate the approaches that were introduced in the "theoretical background" sections. However, there are challenges in demonstrating its practical application for a real organization, considering the broad scope of "business improvement" and "product development". Like any other work in this domain; lack of empirical evidence that correlates business results with the use of a particular assessment methodology was a major challenge in validation of the suggested approach. With this limitation, subject matter expert opinion on the content was relied on heavily as supporting evidence, especially for shaping the 'product assessment questionnaire'. In addition, another key challenge in defining the content for this chapter was the commercial sensitivity of sharing business improvement goals and real data originating from assessments performed in the sponsoring organization. In order to overcome this challenge, a publicized business case will be introduced in section 3.1. This business case will help us illustrate the potential value of using the approaches introduced in this integrated approach. Section 3.2 will attempt to integrate the illustrative business case with a "product development assessment questionnaire". The examples provided in this section attempt to represent this integration by giving examples on how the results of each step can be used as an input to the next step. In Section 3.3, the last step is presented in order to demonstrate some examples for incorporating metrics into the analysis of specific process issues which have already been identified by the assessment questionnaire.

The last chapter of this work discusses the conclusions and future directions. In this chapter we will also highlight the importance of "organizational learning" as a key capability to "learn from assessments" and institutionalize the findings about an organization's improvement opportunities.

After the introduction of a summary in above paragraphs, the overall structure of the thesis is presented below:

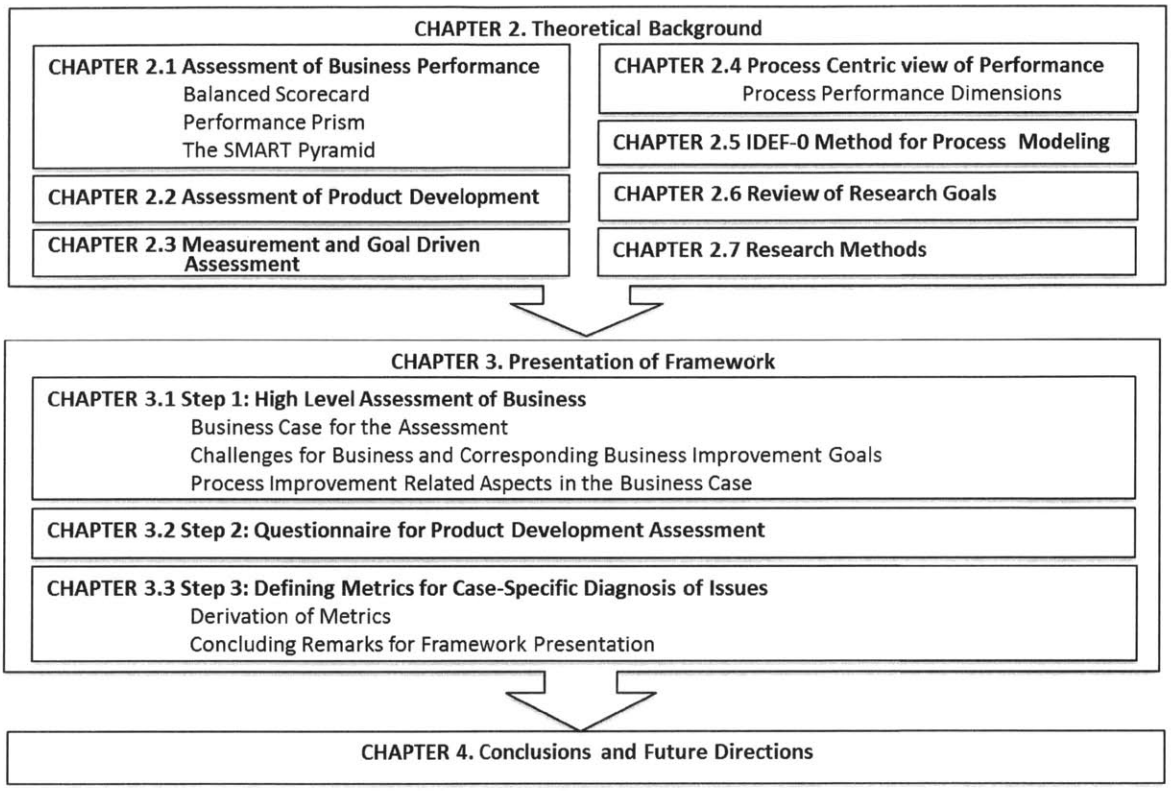

Figure 3 Thesis Organization

2 Theoretical Background

The goal of assessing business performance is an indefinite effort unless specific dimensions of performance have been identified. These dimensions set the focus on one aspect of business and serve as the backbone of an assessment. Literature in defining business performance dimensions is quite diverse. The classification shown in Figure 4 is an attempt to suggest a high level breakdown of different focus areas. Each branch in this figure can be considered to be a discipline for the analysis of businesses, such as: Strategy, Benchmarking, Finance, Valuation, Business Process Improvement, and Performance Measurement. For the purposes of this thesis, we would review the frameworks which are not confined to one field (e.g. financial performance), but suggest a balanced view of different aspects. With this purpose, in the next sections we will review important frameworks, which attempt to depict a comprehensive view of business performance.

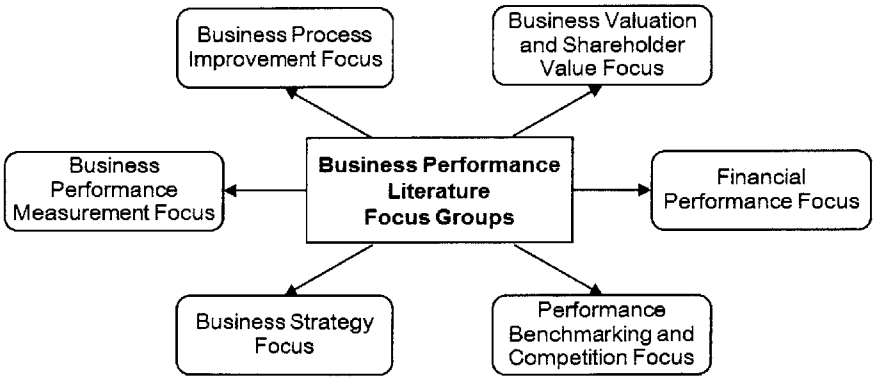

Figure 4 High Level Classification of Business Performance Related Literature

2.1 Assessment of Business Performance

As of today, business assessment remains an unsolved problem. Despite the broad spectrum of approaches and numerous studies in management literature, designing and using business measures and assessments to track and improve performance is one of the most persistent problems that organizations face. In this section, we will attempt to identify some holistic approaches to handling this issue and summarize the most important frameworks in literature. Although these frameworks are not assessments, they provide the most comprehensive guidance on what needs to be assessed in terms of business performance. They present a systematic view of how different aspects complement eachother to create a high-performing business, and highlight the fact that performance measurement/assessment is a systems issue. Before visiting these frameworks, a discussion of the current state of the research in the field is presented in the following paragraph.

Defining and measuring business performance is the subject of research across a diverse set of disciplines such as accounting, operations management, marketing, finance, economics and even psychology and sociology (A. Neely, 2007). The number of scholarly articles in this field is increasing at a steady rate as shown in Figure 5.

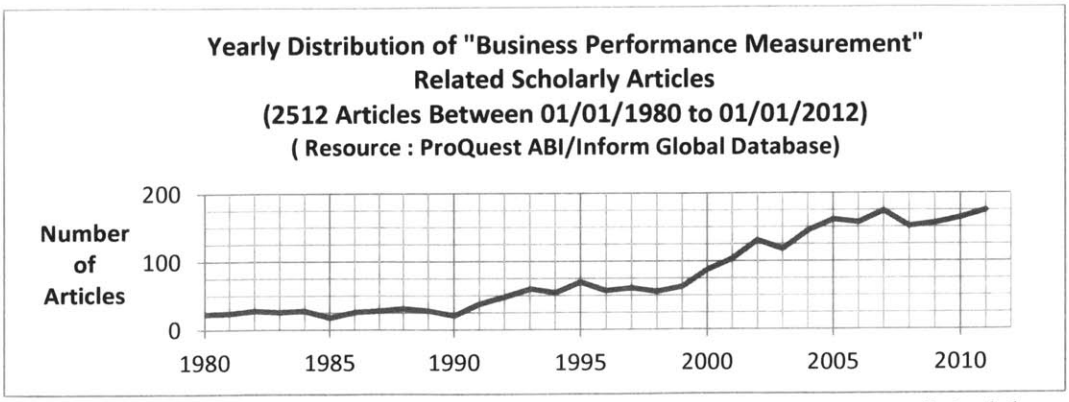

Figure 5 Yearly Distribution of "Business Performance Measurement" Articles

Despite the growing contribution to the field, there are a few studies which suggest a systems level approach to the problem. Problems with performance of a business are usually serious and complex system issues (Meyer, 2007). Although the organizational elements which constitute a business aim to improve their results within their context, the aggregate results can fail to meet expectations of stakeholders. In order to solve issues with performance, consciousness of business performance must be elevated from an elemental view to the system level. This is in contrast to an approach that decomposes business into units and focuses on the performance of the individual elements, on the assumption that if each individual part is improved then the sum of the parts will also be better. The "systems thinking approach" suggests that improvement in the performance of all or some part of a system taken separately may not, and often does not, improve the performance of the system as a whole; in fact, such improvements may destroy the system (Ackoff & Rovin, 2003). One key element of "systems thinking" approach to business performance is a measurement system which can provide a holistic framework (a "big picture") to help business unit leaders assess their business and understand where they should focus performance improvement efforts. In this work, we will visit three holistic frameworks which have a strong influence on shaping the rest of the research in this field (citation numbers provided in the Table 2).

	Framework	Business Performance Dimensions	Reference	Citations
1	Balanced Scorecard	Financial, customer, internal processes, learning & growth	(R. S Kaplan & Norton, 1992)	Over 9000 citations until 2012
2	Peformance Prism	Stakeholder satisfaction, strategy, processes, capabilities, stakeholder contribution	(A. Neely et al., 2001)	Over 500 citations until 2012
3	SMART Pyramid	Quality, delivery, process time, cost, customer satisfaction, flexibility, productivity, marketing measures, financial measures	(Cross & Lynch, 1988)	Over 200 citations until 2012

Table 2 Business Performance Measurement Frameworks

2.1.1 Balanced Scorecard

Balanced scorecard (BSC) is a comprehensive set of performance measures defined along four main dimensions (financial, customer, internal, and learning and growth) that provides a framework for translating the business strategy into operational terms (R. S Kaplan & Norton, 1992).

Balanced scorecard, as the name suggests, promotes a balanced view of performance by looking beyond just financial measures that report the results of actions already taken. The strength of the model lies on the combination of the four key dimensions including: financial perspective, customer perspective, internal business processes, and learning and growth. Evidently, balanced scorecard puts strategy, vision and communication in the center of these four dimensions. A brief explanation for each is provided below:

- Financial; this dimension considers the financial performance of the organization (for example, the profit generated by sales, ROI, project-product profitability).
- Customer; this dimension of performance requires looking at the organization from the customer perspective. Customer satisfaction and brand recognition are examples of measures which are considered.
- Internal Business Process; this dimension represents the internal processes and procedures that are used to operate the business. As an example, some questions that need to be answered from this perspective are; "are the processes focused on reducing costs?" or "do we use technology well enough to support our operations?".
- Learning and growth; this dimension is concerned with the future development of the organization. Adapting skills and restructuring processes in order to improve efficiencies are the subjects of this dimension.

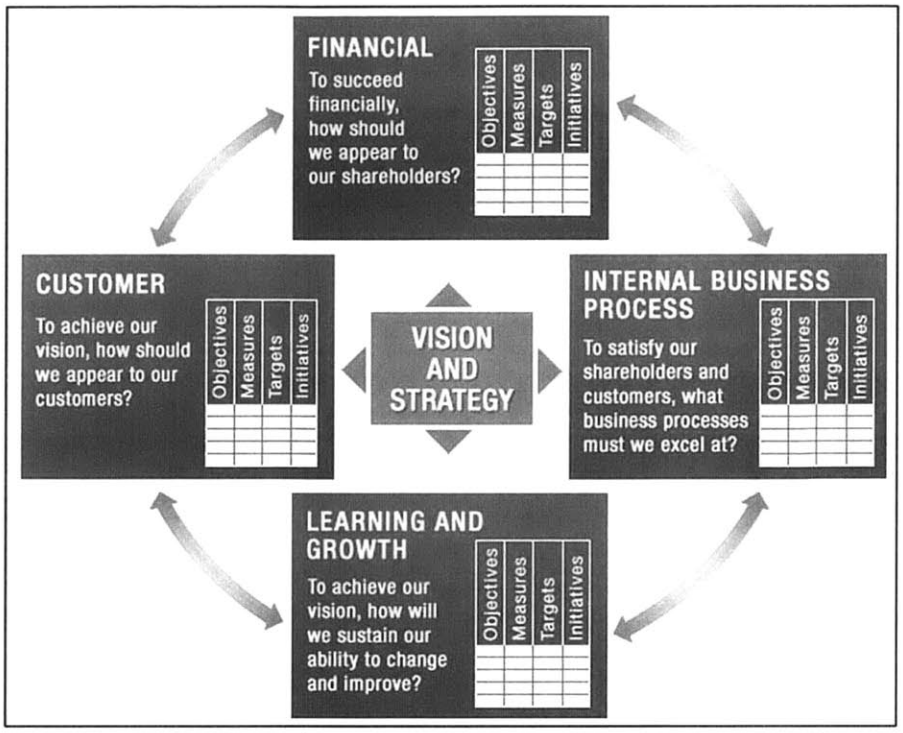

Figure 6 Balanced Scorecard (R. S Kaplan & Norton, 1992)

Implementation of BSC is mostly complemented with a strategy map, which is a one page document that graphically represents the executive level view of organization's strategy and the cause-effect relationship among the goals in the four scorecard dimensions (Robert S. Kaplan & Norton, 2001). Some companies develop a corporate level strategy map as well as the strategy maps for each business unit. An example of a strategy map is shown in Figure 7.

The sub-level maps contain objectives which support the corporate level strategies. With the help of special software, businesses can flow down high-level objectives defined by the strategy maps down to operational levels and aggregate results can be collected automatically (Marr & Neely, 2003).

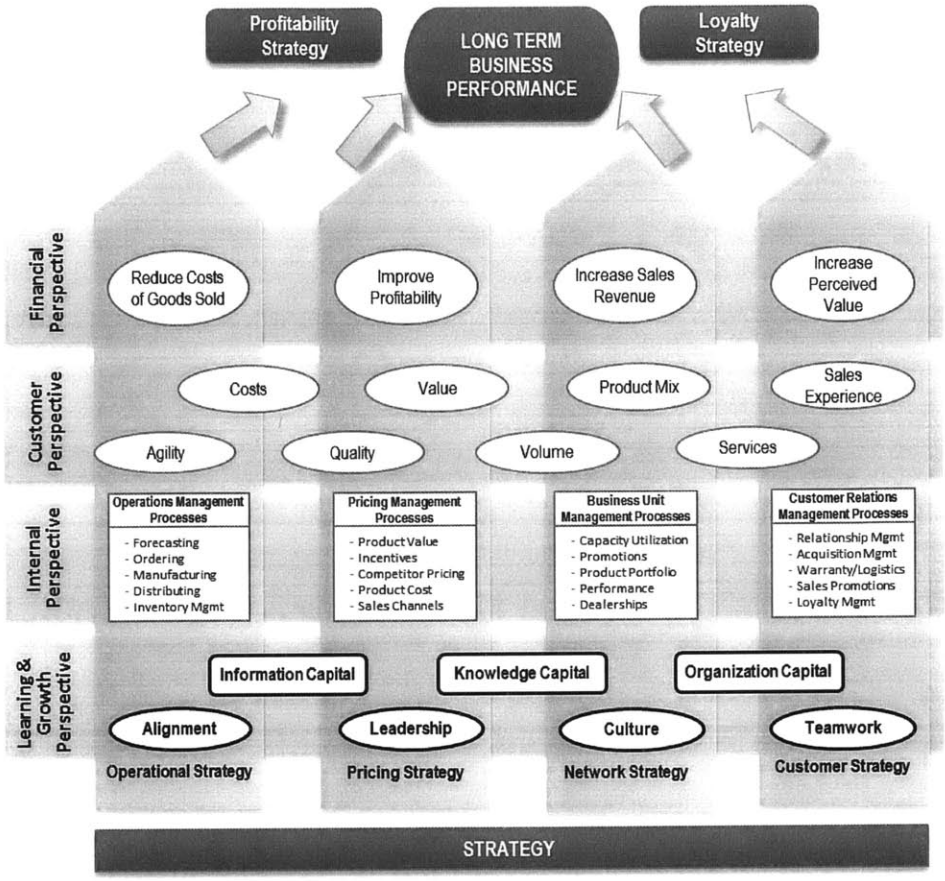

Figure 7 Strategy Map Example for the Balanced Scorecard Approach

2.1.2 Performance Prism

Performance prism recognizes the importance of taking a holistic approach to stakeholder management in business performance. One key point of this approach is that the framework suggests explicitly addressing all stakeholders, not only shareholders and customers but also suppliers, employees, regulators and society (A. D. Neely, Adams, & Kennerley, 2002). This perspective differentiates it from the 'balanced scorecard' approach, which has a vision of deriving measures from strategy. Neely suggests starting the process by thinking about the stakeholders and what they want. This corresponds to the one of the five facets of the prism which is stakeholder's

satisfaction. Other faces of the prism include strategies, processes, capabilities and stakeholder contribution.

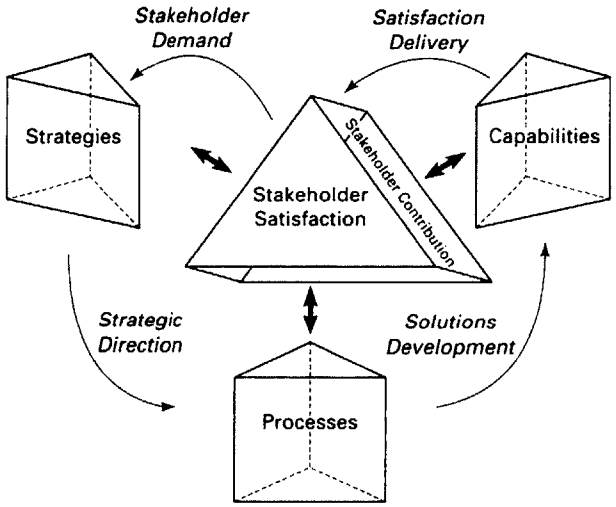

Figure 8 The Performance Prism (A. D. Neely et al., 2002)

Although considerable attention is placed on the process of finding the right strategies that performance measurement should be based on, neglect of issues such as 'how the model is going to be realized' is a limitation of the approach. The lack of guidance on the process of designing measures and deploying the model, as well as unavailability of supporting software are drawbacks for implementation in a practical scenario. In order to design the measures, the 'performance prism' approach identifies five questions for organizations to address when defining a set of performance measures for any setting (A. Neely et al., 2001) (e.g. product development, marketing, sales, and supply chain management):

- *Stakeholder Satisfaction*- who are our key stakeholders and what do they want and need?

- *Strategies* – what strategies do we have to put in place to satisfy the wants and the needs of these stakeholders?
- *Processes*- what critical processes do we need to operate and enhance these processes?
- *Capabilities*- what capabilities do we need to operate and enhance these processes?
- *Stakeholder Contribution*- what contributions do we require from our stakeholders if we are to maintain and develop these capabilities?

Above questions can help an assessor to decompose a business level issue into more granular focus areas.

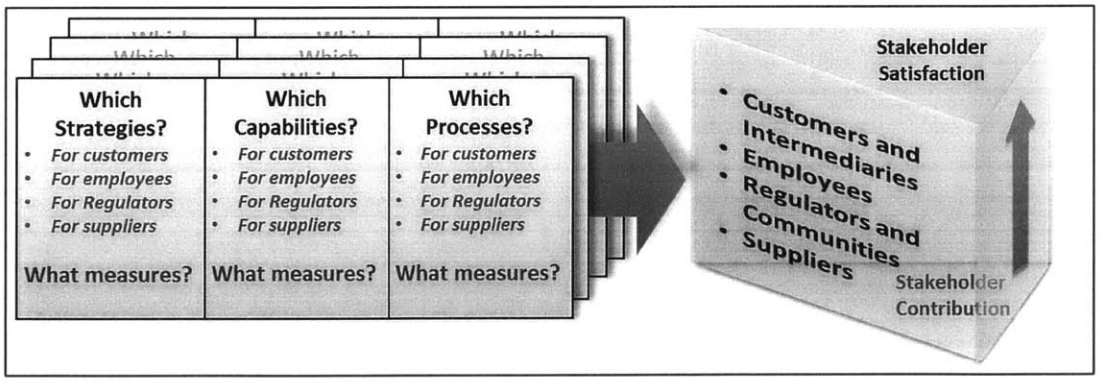

Figure 9 Performance Prism Approach to identify Business Performance Measures

2.1.3 The SMART Pyramid

The SMART pyramid has the goal of linking operations to strategic goals or vision (Cross & Lynch, 1988). The pyramid bricks represent core performances to be measured (see Figure 10) at different levels of hierarchy within the organization therefore enabling functions and departments to align towards the same objective which they placed on the summit of the "pyramid".

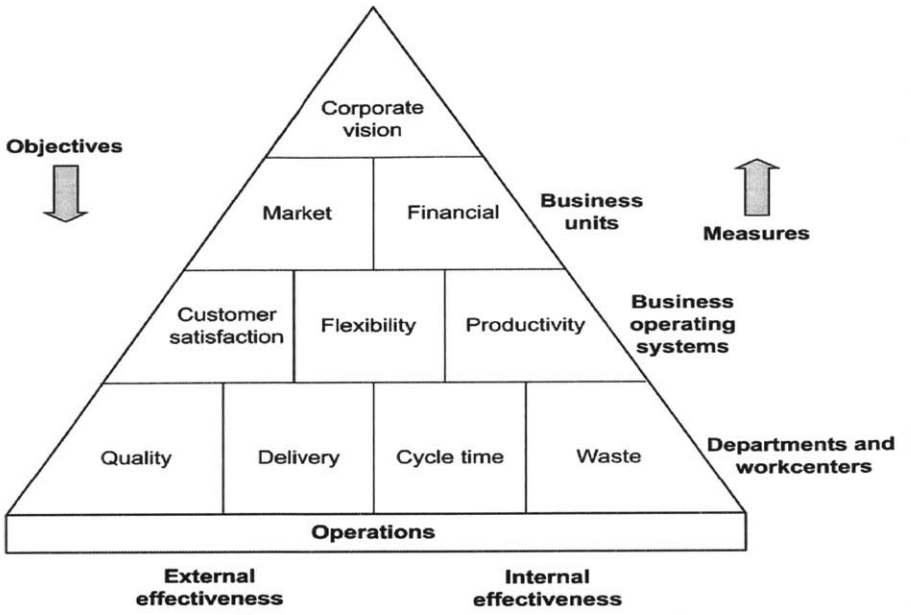

Figure 10 The SMART Pyramid (Cross & Lynch, 1988)

This model combines financial, non-financial as well as operational and strategic indicators of performance. SMART pyramid suggests a layered approach to represent the interaction between business units and individual business activities, and hence attempts to align operational performance indicators with corporate objectives. According to Lynch and Cross achieving this objective starts with achieving success in four key operational measures (quality, delivery, cycle, and waste) at the operations level, at the bottom layers of the pyramid. The middle level indicators bridge the gap between the top level indicators and operational level by focusing on customer satisfaction, productivity, and flexibility.

One weakness of this model is the lack of any mechanisms to identify key performance indicators. However, some organizations like Boston Finance Group (BFG) have interpreted SMART pyramid (see Figure 11) and included key performance indicators (Lynch & Cross, 1999). BFG's implementation is an example of how a system of

performance measures / indicators (both financial and non-financial) can be structured in a hierarchical framework which decomposes strategy level measures to operational measures.

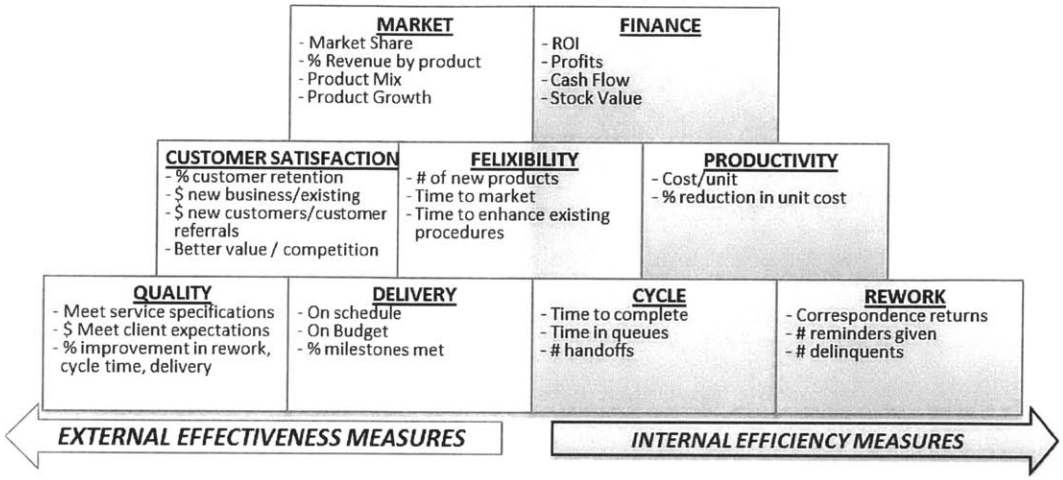

Figure 11 Boston Financial Group's Interpretation of SMART Pyramid

2.2 Assessment of Product Development

The approaches presented in the previous section can be seen as a model of business performance. However, in order to operationalize these models, assessment of the organization, which will depict the existing picture, is necessary. Business performance assessment systems are the formal, information-based routines and procedures managers use to maintain or alter patterns in activities of the business (Simons, 1995). A typical assessment helps businesses in setting the right goals, providing feedback to managers on progress towards those goals, and identifying gaps so that interventions for improvement can be planned. However, assessment and control of business performance is becoming more challenging for many businesses due to the increasing complexity of organizational structures and growing number of processes (Julian

Birkinshaw & Suzanne Heywood, 2009). In order to deal with this complexity, businesses are forced to tailor their high-level assessment templates, and create process/ context specific assessment questions for being able to diagnose the problems at all levels. However, if this tailoring is not done in a systematic way, unstructured assessment systems may impose additional challenges for business unit leaders in seeing the "big picture" of their business and understand where they should focus performance improvement efforts. Also, internal consulting units, which are expected to support business units in identifying performance gaps, lose efficiencies due to extra time and effort required to understand the assessment systems which are used in the organization.

As introduced in section 1.3, one of the goals of this work is to introduce a method which will have practical applications for a product development organization. In order to achieve this, use of a questionnaire, which is focused on identifying the gaps and improvement opportunities in development and engineering functions of the organization is suggested. The intent of the questionnaire is to enable either business unit managers or internal consultants to evaluate productivity, efficiency and effectiveness of a business with the goal of identifying areas to focus improvement efforts. In this work, we will refer to the PDSAT questionnaire which has been developed to help businesses assess the maturity of their product development related activities.

PDSAT is a holistic and integrated self-assessment questionnaire for product development (Knoblinger, 2011). The questions are derived from product development best practices, current literature on product development and survey results on requirements for self-assessments collected from industry focus groups. The Perform Questionnaire is an assessment survey to explore the product development (PD)

capabilities of an organization and was developed at MIT (Tang, Liu, Seering, & Otto, 2005) and a predecessor to the PDSAT. The assessment tool leverages previous work on product development focused surveys, previous academic research and industry practices to define a set of questions which address the PD capabilities of the organization. In order to enable integration with other self-assessment questionnaires, which might be already in use for process improvement in the organization, questions are mapped to the Capability Maturity Model Integration (CMMI), the Malcom Baldrige National Quality Award and the LESAT, a lean enterprise self-assessment tool.

The PDSAT questionnaire comprises 91 questions based on a five-scale maturity-level rating method (Knoblinger, 2011). These questions are grouped under 25 categories, each representing an important aspect of product development. Table 3 below shows the mapping of these categories onto the dimensions defined by "business performance frameworks" which were introduced in section 2.1.

Table 3 Product Development Assessment Questionnaire Mapping to Business Assessment Frameworks

The mapping in Table 3 characterizes the number of questions in PDSAT in terms of its focus areas. As shown in Figure 12, the questionnaire addresses some aspects of those focus areas more than others.

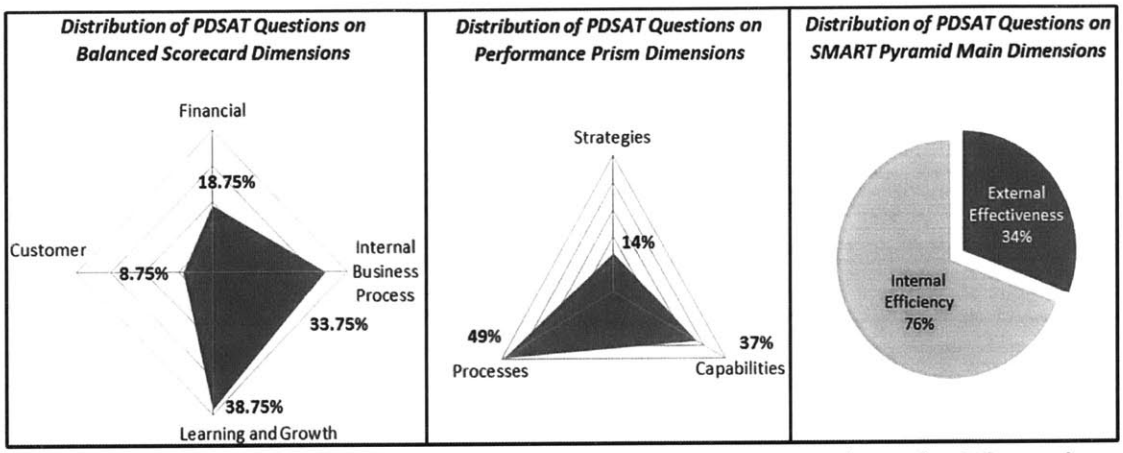

Figure 12 Evaluation of Product Development Assessment Questionnaire Dimensions

As seen in the evaluation, the PDSAT questionnaire is more focused on internal efficiencies compared with external effectiveness factors. It is also more process-oriented, and strategy and capability factors receive less emphasis. The results on balanced scorecard dimensions show that, "learning and growth" and "internal processes" receive more focus more compared with customer and financial aspects of product development processes. With this evaluation, PDSAT appears to be a good candidate for assessment of internal processes and capabilities of the organization in the domain of product development, once the strategic and financial issues of business have been analyzed by corporate decision making processes.

2.3 Measurement and Goal Driven Assessment

The frameworks which have been introduced in section 2.1. are useful for viewing business from a holistic perspective and defining the high-level indications of performance gaps. However, business activities in an organization have a large spectrum and can occur at many different levels within the hierarchy. Many activities, which take place in the organization, must be analyzed within their own context considering the specific goals that they serve. Goal-based approaches rely on development of customized performance measures which depend on the specific circumstances in which the activity is taking place. Measures of success need to be oriented towards the specific goal of the activity. A goal-based measurement approach requires "definition of a measurement program based on explicit and precisely defined goals that state how measurement will be used". The most widely known method for applying goal-oriented measurement is the Goal/Question/Metric (GQM) method. GQM can be used to assist all of the frameworks which have been described in previous sections. GQM approach connects a "goal" with specific measures (metrics, indicators) of performance for diagnosing a specific case.

The GQM method is used as a basis for the design of the measurement program to identify metrics for the goals of an improvement activity. The reason for selecting GQM as a method to complement the assessment task is presented below:

- GQM is explicitly focused on measurement-based process improvement, as opposed to Statistical Process Improvement methods such as CMMI (SEI, 2010). Therefore, it can be used in areas where processes have a short history, or statistical data is not available. These limitations apply to many functions which take place in the early stages of product

development, or one-time activities of the organization such as introducing new products and services.

- GQM has been developed to be used by a third party assessor, who has the goal of diagnosing an issue and identifying the quantifiable data to analyze the issue further. This scope is aligned with the motives of this thesis and the envisioned scenarios of practical implementation by process improvement consultants in an organization.

In the following section, GQM and GQIM methods will be introduced.

2.3.1 Goal-Question-Metric (GQM) Method

Goal-Question-Metric approach was originally developed for evaluating problems for a set of software-centric projects in the NASA Goddard Space Flight Center environment. GQM's approach to these challenges was to develop rationale, traceable and efficient measurement strategies according to the underlying improvement or strategy goals. Although the approach was originally used to define and evaluate goals for a particular project in a particular environment, its use has been expanded to a larger context.

The main principle of GQM is; assessment should be goal-oriented. Therefore, the model suggests a hierarchical structure starting with a goal which specifies the purpose of the assessment, (Basili, Caldiera, & Rombach, 1994). These goals can be refined into questions which will help to solve the goals. Based on the goals and questions, metrics are defined (or selected). The same metric can be used in order to answer different questions under the same goal. GQM procedure can be seen as a three layered structure, as illustrated in Figure 13.

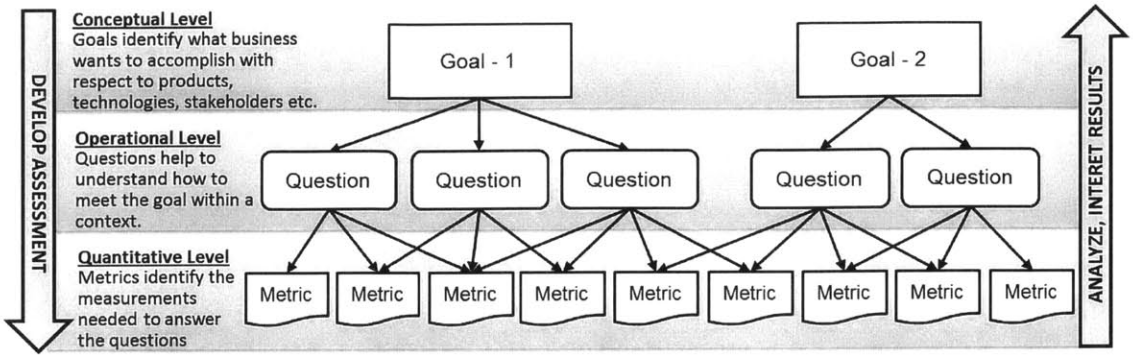

Figure 13 GQM Model Hierarchy - Adapted from (Basili et al., 1994)

The three levels which constitute the hierarchical structure of the model are: conceptual, operational, and quantitative levels. At the conceptual level, the set of measurement goals are defined for different points of view. The operational level decomposes the goals by identifying a set of questions that are related to the performance problem (issue). The quantitative level associates quantifiable variables to the determined questions. These variables can be either objective or subjective, depending on what they are measuring.

GQM can be considered as a methodology for conducting efficient assessments by defining the right set of metrics needed to assess satisfaction of goals. The approach can be implemented in a diverse range of organizations, environments, products, processes or resources. Implementation requires a six-step process where the first three steps are about using business goals to drive the identification of the right metrics and the last three steps are about gathering the measurement data and making effective use of the measurement results to drive decision making and improvements. These steps are as follows:

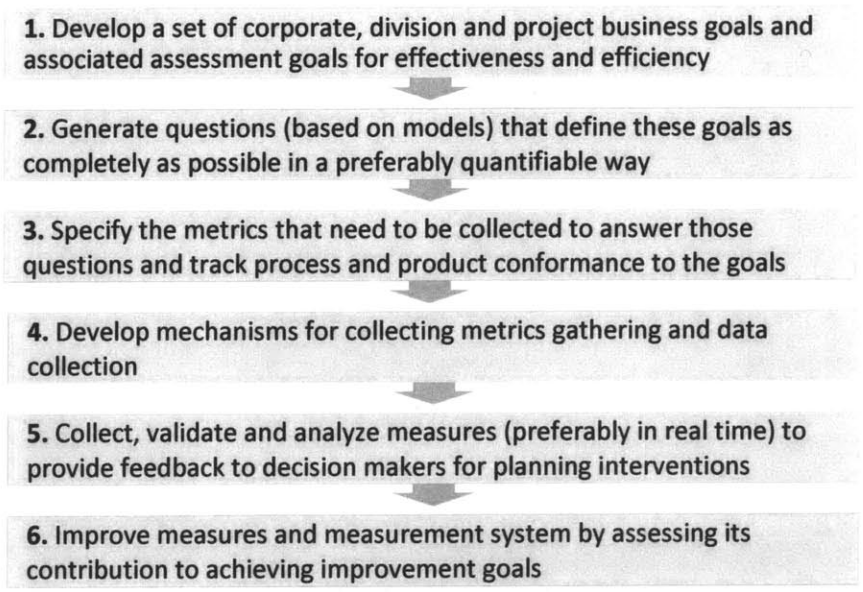

Figure 14 Goal-Question-Metric Steps in Assessment System Implementation

Weaknesses have been reported for the GQM approach as well. The most outstanding weakness of GQM is the risk of identifying more metrics than needed. Therefore, "prioritization" or categorization of goals and questions is required to assess different dimensions of situation and balance measures of performance.

2.3.2 Goal-Question-Indicator-Metric (GQIM) Method

Goal-question-indicator-metric model is developed at the Software Engineering Institute (SEI) and is an extended version of GQM (Park, Goethert, & Florac, 1996). GQIM, similar to GQM, aligns measures and indicators with business goals, ensuring that the measures and performance indicators selected will be used to show success in achieving these goals. However, an intermediate step for "indicators" is added to GQM in order to assist in linking the questions to the measurement data (Goethert & Fisher, 2003). This interim step helps to link the measurement data or metrics that will be collected with the measurement goals.

GQIM starts by first identifying high-level business goals and then decomposing them into operational statements or sub-goals with a measurement focus. These sub-goals are then translated into measurement goals. Decomposition of each high-level goal requires derivation of a set of questions whose answers lead to statements that identify the type of KPIs or metrics needed. The overall process is illustrated in the figure below:

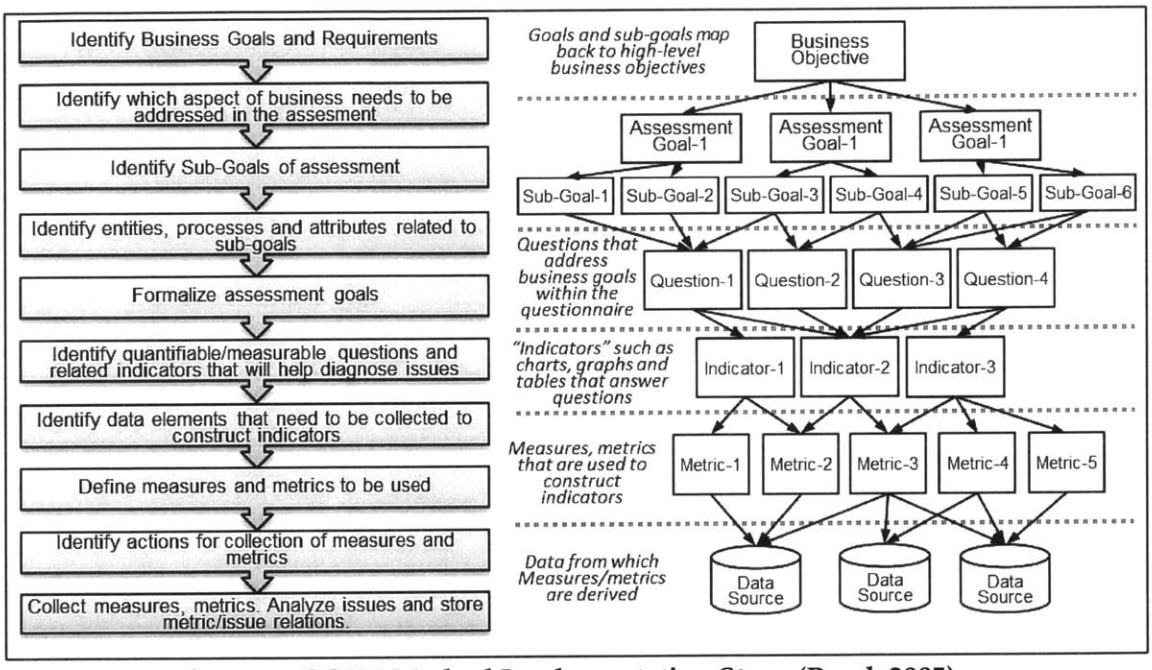

Figure 15 GQIM Method Implementation Steps (Boyd, 2005)

2.4 Process Centric View of Business Performance

Independent of the framework or methodology, creation of the process view of an organization is an essential element to understand the organization and issues for any type of business improvement initiative. An organizational system is a set of business processes which take input from upstream activities and feed downstream activities. Success of the business is a result which emerges from high performing processes which

operate in harmony at all levels, similar to elements of a good system. In this section, we will visit the process view of a business and the definitions of performance for a process.

The main objective of creating a process model of the organization is to be able to depict how business results are created by activities of the organization, and controlling and managing the factors that affect these processes in order to increase the effectiveness and efficiency of all value creating functions of the organization. From an operational point of view, this requires having defined processes, measuring their performance, and improving them incrementally. The performance goals for processes can be defined "top-down", based on benchmarking results, goals derived from business strategies, corporate initiatives, or future vision of the organization. The Sink&Tuttle's representation (Sink & Tuttle, 1990) shown in Figure 17, attempts to highlight the key importance of business processes as the central block connecting upstream and downstream system in an organization to growth, competitiveness and desired goals of the business.

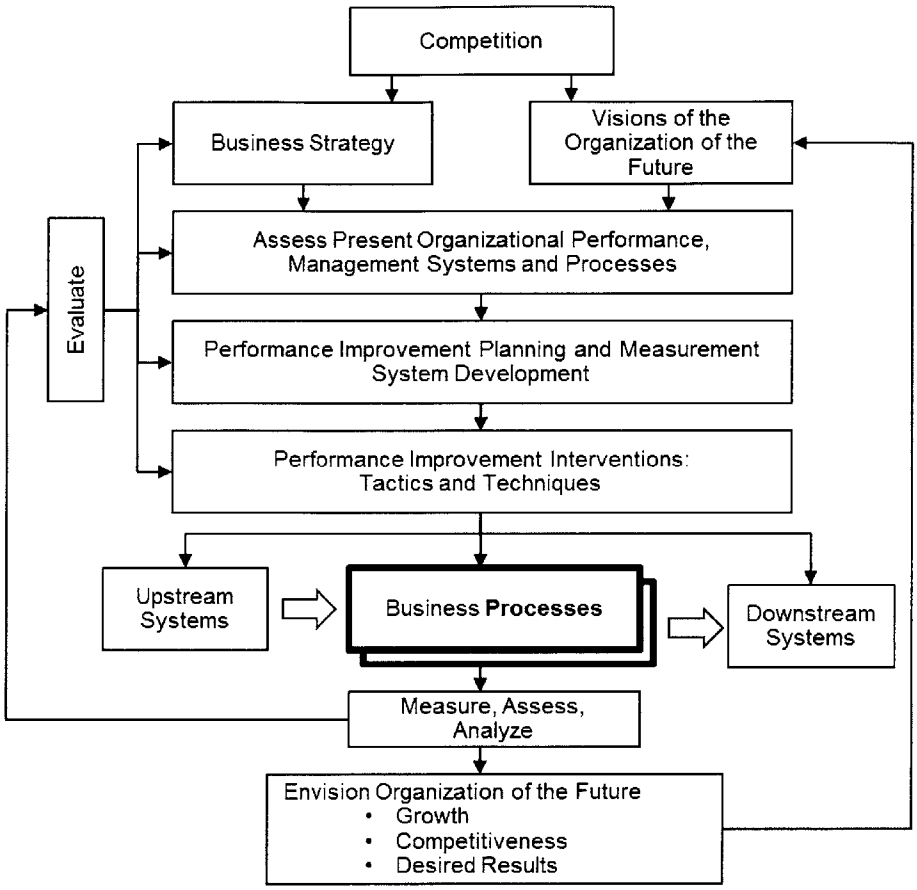

Figure 16 Process; the center of organizational system and performance - adapted from (Sink & Tuttle, 1990)

According to Sink& Tuttle model of organization, processes are controlled by the directions (or objectives) which flow down from business strategy decisions or improvement activities. This is similar to the Balanced Scorecard and SMART Pyramid approaches, which have been discussed in Section 2.1.1 and 2.1.3 respectively. Although the decomposition of 'high-level vision and strategy' to 'downstream operational goals' is a common theme in all of these frameworks, Sink&Tuttle's model refers to "business processes" to handle this hand-over. This model also highlights the importance of

measurement and assessment for organizational improvement for better business results, referred as "envision organization of the future" by the authors.

2.4.1 Process Performance Dimensions

For the assessment and analysis of a process, most of the authors refer to the generic measures of "effectiveness" and "efficiency". However, in literature and practical use, there is great deal of confusion in meaning of these terms. Table 4 summarizes some of these definitions.

Efficiency Definition	Effectiveness Definition	Reference
Efficiency is an input an transformation process question, defines as the ratio between the resources expected to be consumed and actually consumed process	Effectiveness, which involves the right things, at the right time, with the right quality, can be defined as the ratio between actual output and expected output	(Sink & Tuttle, 1990)
Efficiency is the ratio of actual output attained to standard output expected, and reflects how well the resources are utilized to accomplish the result	Effectiveness is the degree of accomplishment of objectives, and shows how well a set of results is accomplished	(Sumanth, 1998)
Efficiency is a measure of how economically the firm's resources are utilized when providing the given level of customer satisfaction	Effectiveness refers to the extent to which the customer requirements are met	(Andy, Mike, & Ken, 2005)
Efficiency means how much cost is expended compared with the minimum cost level that is theoretically required to run the desired operations in a given system	Effectiveness in manufacturing can be viewed as to what extent the cost is used to create revenues	(Jackson & Petersson, 1999)

Table 4 Efficiency and Effectiveness Definitions in Literature

Sink and Tuttle's definition is one of the most widely accepted one. The authors also establish a very high level model to depict the causal relations between "efficiency, effectiveness, quality" and "business growth and success" (Sink, Tuttle, & Devries, 1984).

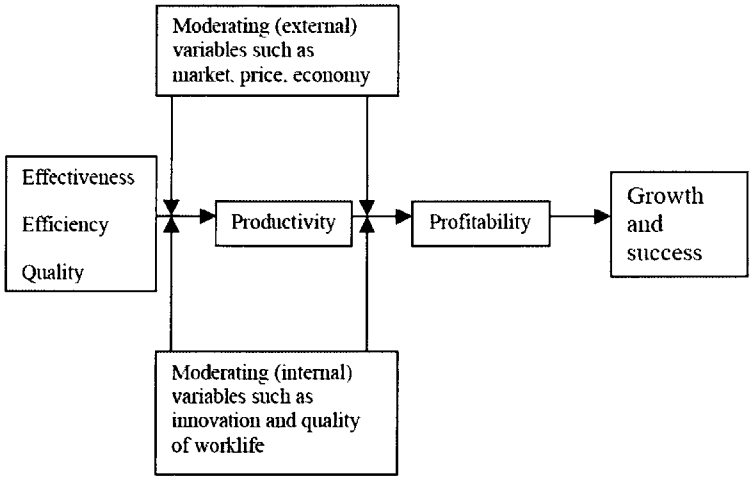

Figure 17 Sink and Tuttle Model for Causal Link between Performance Variables and Success

In this high level model, "quality", "productivity" and "profitability" also play an important role. However, these terms also have a broad scope and do not have a single accepted definition in literature. "Productivity", being one of the most widely referred measures of performance, has the widest variation in its definition depending on the context it is defined within. In general, it can be defined as the relation of output (e.g. products, results) to input (consumed materials or resources) in a transformation process. "Profitability" is a result of performance of the products and services of the business processed by the mechanisms of market and competition (see Figure 18).

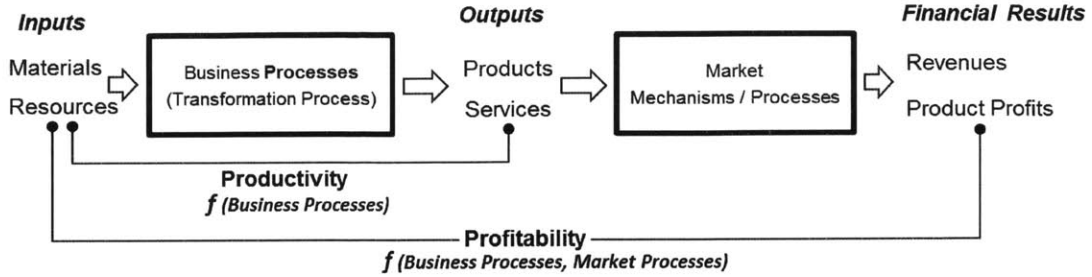

Figure 18 Profitability and productivity

In addition to the effectiveness and efficiency, as commonly accepted measures of process performance, we will introduce another dimension; "goal setting". This can be explained with a simple analogy of shooting at an unknown target. With the addition of "goal setting", the overall performance can be abstracted into three main dimensions.

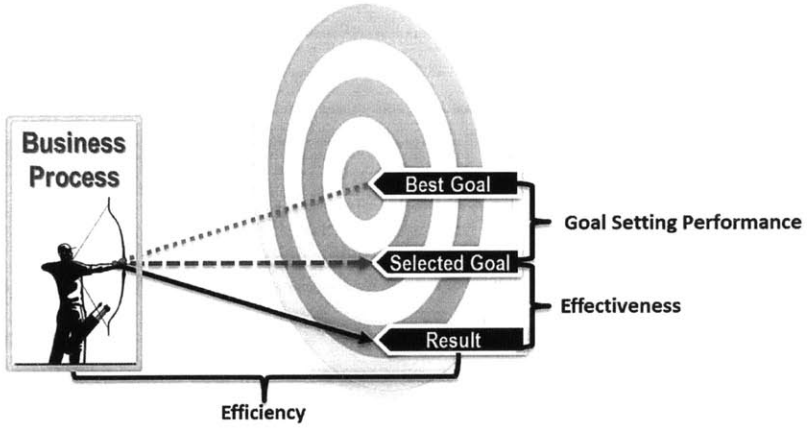

Figure 19 Three dimensions of performance

- *Goal Setting Performance:*

  Best goal may not be selected at first place due to uncertainty and unknown unknowns in the environment. The difference between the "best goal" (which may not be known at the time of objective setting) and the "selected goal" is an

indication of "goal setting performance". (e.g. introducing a new product to the market with a new set of features). In order to maximize this performance for business, it is essential to develop capabilities to predict external market conditions, analyze uncertain factors and perform an extensive analysis of external stakeholder behavior which might influence the value of process outcomes.

- *Effectiveness:*

  We will define effectiveness as the capability to meet objectives despite the effects and disturbances causing variations in the value of output. The difference between the objectives of activities (or processes) and the actual results achieved is an indication of effectiveness.

- *Efficiency:*

  Efficiency is the comparative measure of value of results achieved and the cost of achieving these results. These costs may arise due to allocation and use of resources as well as the inputs consumed or transformed for creating the outputs.

These performance dimensions will be incorporated into the IDEF0 process view. In order to use processes as the unit for assessing performance of a business, modeling the organization is a key activity. In section 2.5, IDEF-0 is introduced as a flexible and strong process modeling methodology to do this.

2.5 IDEF-0 Model for Process Modeling

In this section, we will review the IDEF0 process modeling methodology in order to identify a systematic approach to represent the processes of the organization. IDEF0 Modeling method is designed to model the processes that represent actions and activities of an organization or system. It was derived from the established graphic modeling language "Structured Analysis and Design Technique" (SADT) language (syntax and semantics) and a description of a comprehensive methodology for developing models (Marca & McGowan, 2006).

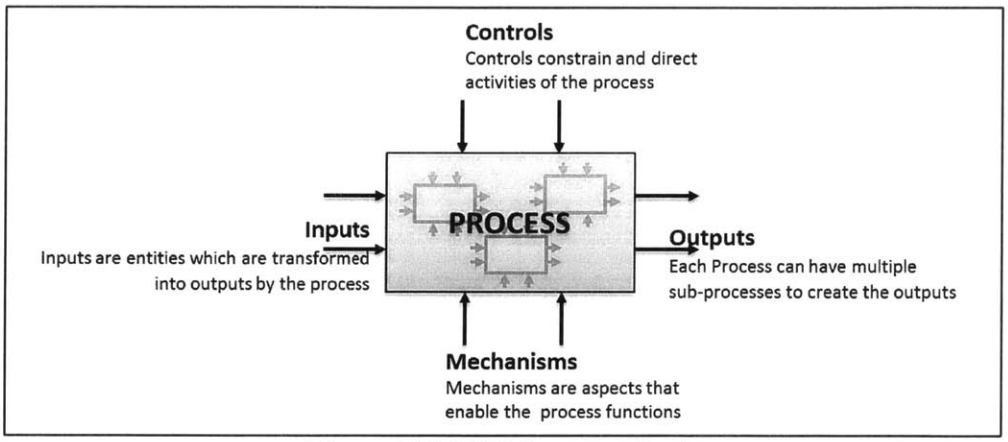

Figure 20 IDEF0 Process Block

IDEF0 models assist in representing processes and provide effective communication of the business activities at all levels. An IDEF0 block identifies; functions performed within the process, entities needed to perform the functions, the elements that control these, and the mechanisms that enable the functions and the outputs created. Therefore, the model, in graphical form 'tells the story" of what the process does.

In the case of product development, the objectives of the process can be the specifications, regulations, standards, financial goals, quality, and schedule objectives. The inputs are the materials and other consumables that are used to produce the

product. Development of the product requires allocation of resources such as technology, human resources, energy, infrastructure, tools and equipment.

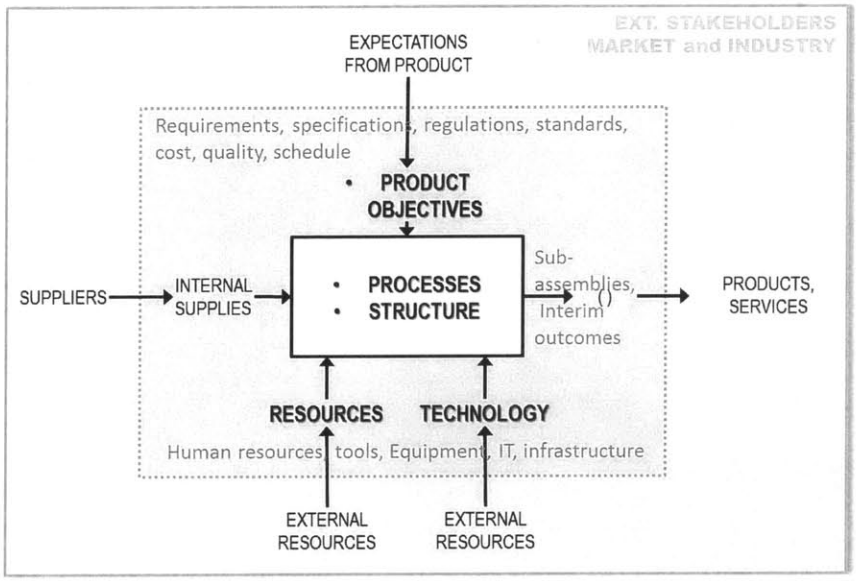

Figure 21 Generic Representation of I/O for IDEF0 Process Block for Product Development

IDEF0 is as a largely structure-oriented diagramming technique that enables representation of the interactions between different activities in the organization. The hierarchical structure of IDEF enables an integrated view of activities at different levels. Figure 22 represents the product development processes at multiple levels (Zhao, Xu, Kramer, Proctor, & Horst, 2011).

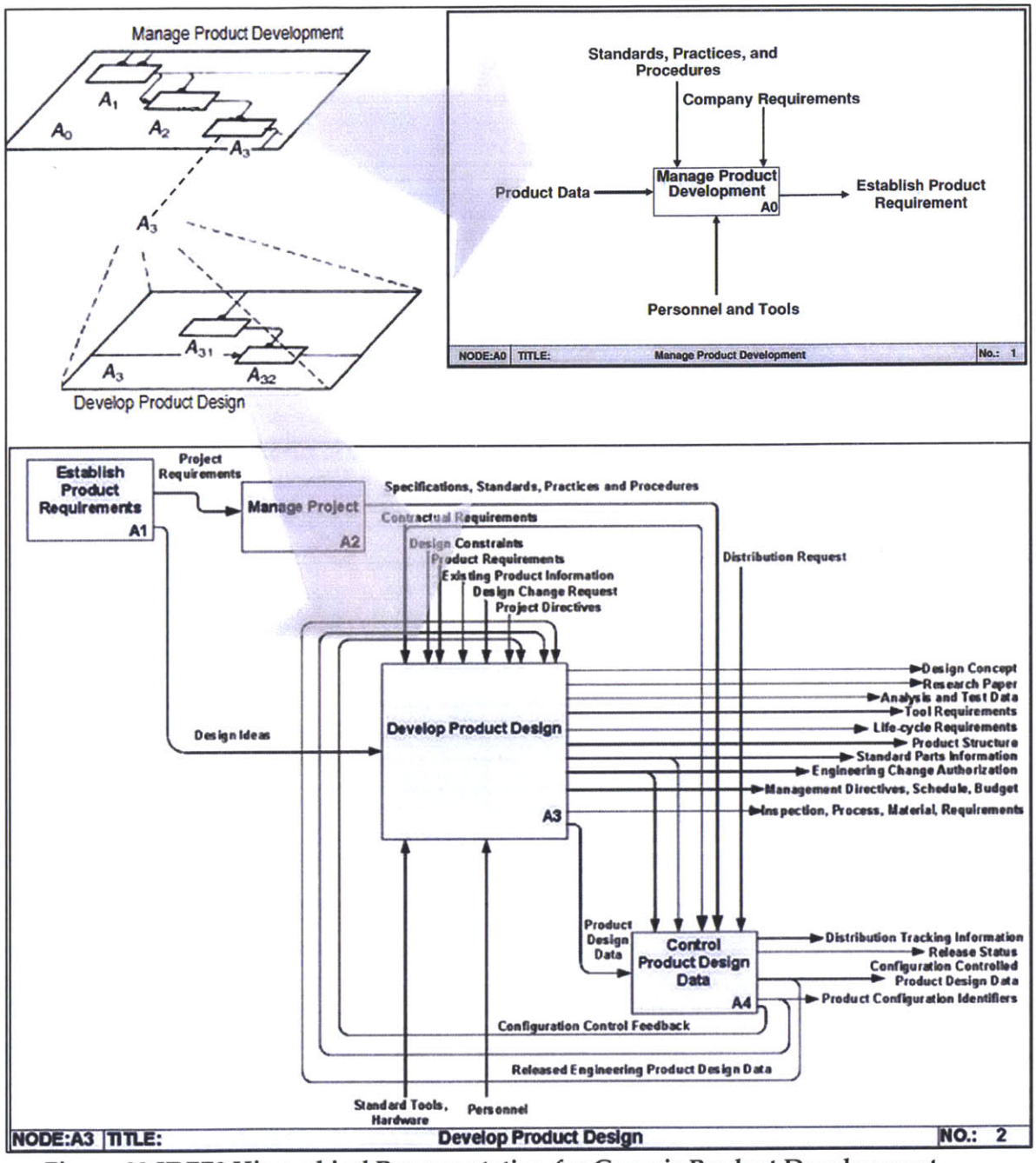

Figure 22 IDEF0 Hierarchical Representation for Generic Product Development Processes (Adapted from Zhao et al., 2011)

One important discussion for the purposes of this thesis is how to make use of the structural approach of the IDEF0 model to help the analysis and decomposing of a performance issue to specific problems. For this purpose we have to look for answers to the following questions; "how does this block representation help us ask intelligent questions about process performance?" and "how can we incorporate the effectiveness, efficiency dimension onto a process modeling tool?"

First we will show the performance dimensions on the unit process block. In the literature, there are studies which utilize "effectiveness" and "efficiency" in conjunction with IDEF0 such as the one proposed by O'Donnell and Duffy (O'Donnell & Duffy, 2002) where they further develop the activity model of the IDEF0 framework. We will add the "goal setting performance" aspect to the existing measures of "effectiveness" and "efficiency".

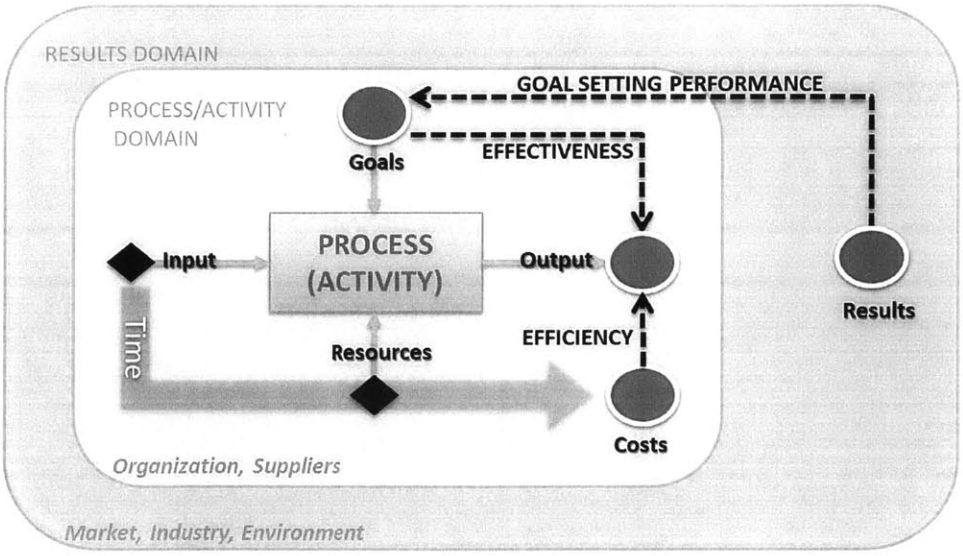

Figure 23 Performance dimensions for IDEF0 Process Block

Second, it must be noted that, an IDEF0 process block can act as a conversion unit for different types of entities acting as inputs, resources or objectives of an organizational

activity. The comparison between the attributes of the inputs, outputs, objectives and cost of resources are measures of success for the process.

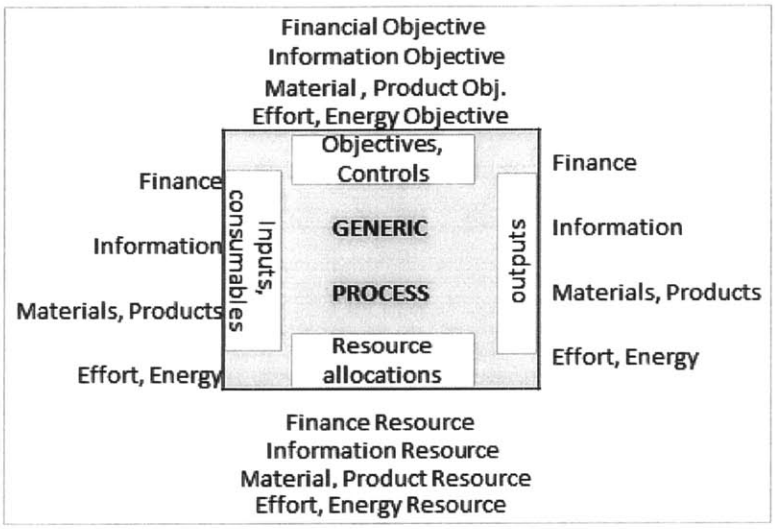

Figure 24 IDEF0 block as a conversion unit

The performance of a process can be thought as a comparative measure of the attributes of the inputs and outputs to the block. A process can convert a financial objective into an information output about product strategy using human resources, and this information can be used as an objective for project management. Or, a material can be converted into a product using human, finance, energy resources with a project objective. These examples are demonstrated in the figure below:

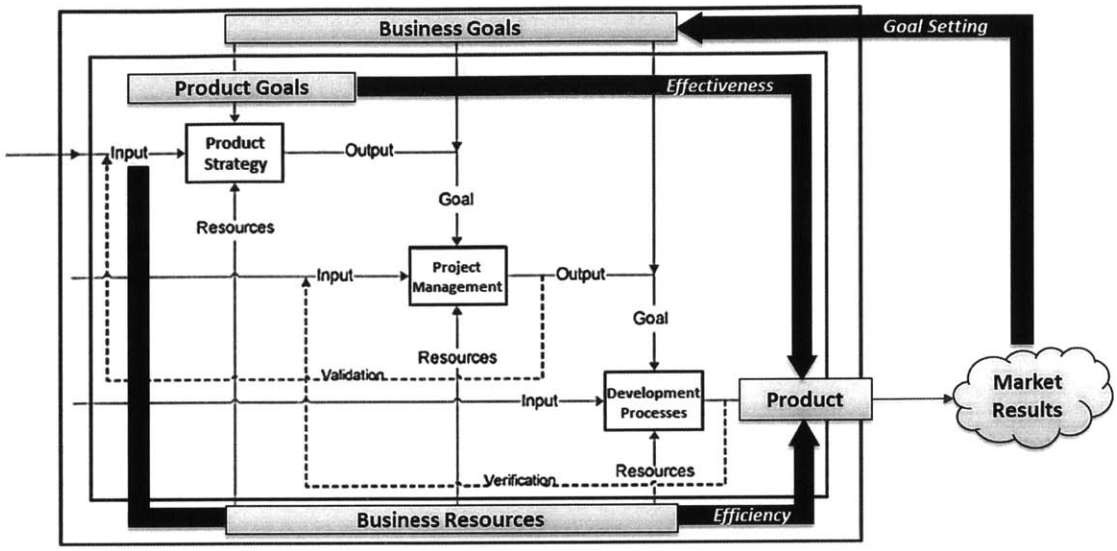

Figure 25 Main Performance Dimensions for Product Development -Adapted from (Cedergren, Wall, & Norström, 2010)

The main goal of the attempt to introduce the view shown above is that, the performance of the product development function depends on both the effectiveness and the efficiency of the activities performed as well as the success in defining the goals for these activities. Usually, time, cost, and quality constraints are used to evaluate the success of product development projects (PMI, 2004). Such an approach may easily shift the focus to the resources consumed and the output of the product activities. Therefore, if a product is developed on time and on budget, it may be deemed to be successful. However, a very successful project does not always yield successful products if the product goals are not selected correctly. On the other hand, a promising goal will not guarantee success if the organization is not able to comply with the objectives (effectiveness). Even if the goals and compliance with goals is in place, the costs of achieving results may be too high, limiting the success on the financial aspects. As a result, ignorance of one of these performance dimensions will yield a limited perspective to self-assessment in the domain of product development.

2.6 Review of Research Goals

In today's competitive environment the need for deploying product development investments more efficiently and effectively is stronger than ever. In this environment, self-assessments and measurement of the performance of the product development activities is a key capability for the success, and in some cases survival of the business. With this strong motive, we have reviewed studies from a variety of authors and disciplines to help us establish a knowledge basis for performance assessment in general. Performance assessment has attracted attention from many researchers with different functional backgrounds. Unfortunately, no body-of-knowledge has emerged as a dominant approach despite the large volume of research effort. In an attempt to initiate a body-of knowledge Andy Neely edited a book, Business Performance Measurements (A. Neely, 2007) with contributions from researchers from different business domains. We have also reviewed the "Performance Prism" approach in section 2.1.2 from the same author.

Although systematic approaches on business performance (Balanced Scorecard and SMART Pyramid) are comprehensive in terms of their "business-level" content, practical operationalization of these at the level of "product development" processes requires further decomposition and analysis.

On the other hand, product development-related assessment questionnaires are highly practical tools which assist analysts to identify the focus areas and possible candidates for interventions. However, scoping the boundary of processes can be an issue for the assessor. For this purpose, we have reviewed the IDEF0 method to serve as a map for the assessor in identifying the boundary of related processes as well as interactions between the activities within the boundary. Finally, we have discussed the basics of

GQM methodology. GQM's top-down approach does not provide guidance on what the "goal" should be. However, it strongly asserts that, whatever the goal is, it should be tied to a set of measures by direct questions addressing the concerns/issues/gaps (therefore, the goal in GQM is the remedying the gap addressed by assessment).

With these observations about the existing research in the field, it is hard to address a specific research gap in the existing approaches. We would rather focus on the integration of these different perspectives that are already validated in their own domain. Therefore, the research goal for this work is to present a view of how these approaches may be used together in an integrated fashion and provide guidance to an assessor to establish his own assessment method starting from business-level goals to operational-level metrics. In the next Chapter we will present the application of the framework which was developed with these goals. However, before starting our discussion about application, we will go over the research methods used in the following paragraphs.

2.7 Research Methods

This research was sponsored by a process improvement consulting organization operating within a global business with core strengths in product development. The main requirement for this research was to develop a comprehensive assessment which can be used to define the maturity level of product development. In order to satisfy this requirement, an extensive literature survey was conducted and existing research in the field of product development assessments was reviewed. MIT Lean Advancement Initiative's strong background in the field provided opportunities for analysis of a number of research outcomes derived from studies with real organizations and domain

experts. As a recent and comprehensive asset of this research portfolio, the 'Product Development Self-Assessment Tool – PDSAT" (Knoblinger, 2011) questionnaire was used as a starting point and the structure and content of the questionnaire was further developed to reflect the needs of the specific organization.

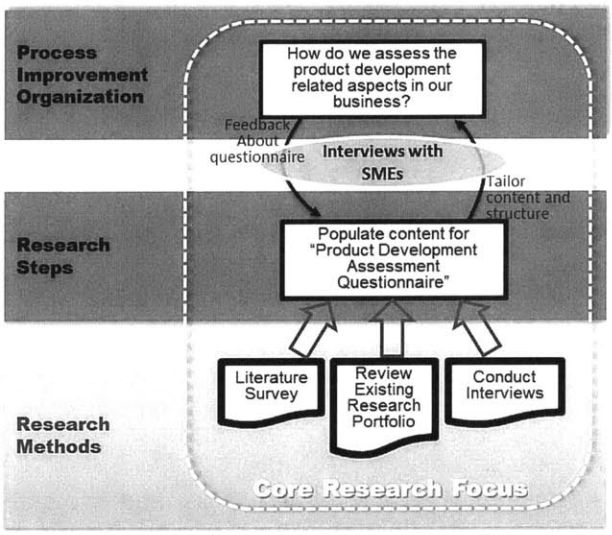

Figure 26 Research Methods to Support the objective of developing a "product development assessment" questionnaire

Interviews with subject matter experts in the organization was the main research method to adapt research outcomes (mainly the questionnaire content) to address the initial need of being able to assess the product development related aspects in business units. Within the course of developing and tailoring content, feedback was collected in a total of 14 interviews with corporate-level consultants.

During the course of interviews a key observation was the extensive use of complementary knowledge and experience that the subject matter experts referred to when explaining their process of performing product development assessments in local business units. In all of the real-cases which were discussed, 'product development assessment' had a background related to 'business goals of the organization' and had

follow-up actions for 'detailed analysis of domain specific processes and metrics'. This feedback led to the observation that *'improvement of processes is mostly a part of a bigger picture'*, and in order to be able to convey the complete story a top down approach, starting from business improvement goals down to metrics, is necessary (see Figure 27).

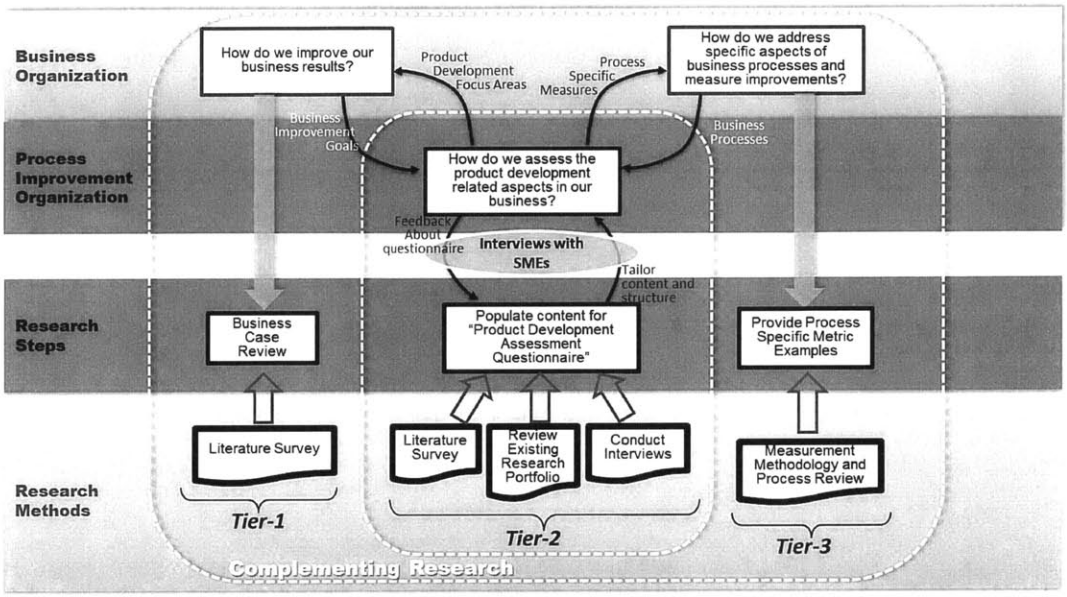

Figure 27 Complementary Aspects of "Product Development Assessment"

In order to be able to address the complementary aspects to 'product development assessment' (represented within Tier-2 block of research activity in Figure 27), additional elements had to be incorporated into this thesis. These complementary aspects were formulated in a three-tier structure: "Tier-1: An understanding of high-level business goals", "Tier-2: An assessment to analyze product development related aspects which contribute to these goals" and "Tier-3: Performance measures of domain/product specific processes". The core focus, "Product Development Assessment", is an interim step in the middle; which serves the top level business improvement goals and feeds from the processes/activities at the bottom.

The method used in this thesis for addressing 'business goals' aspect (Tier-1) of improvement initiatives is to present a business case that gives background information about a typical improvement initiative. In order to avoid the use of commercially-sensitive information collected from the sponsoring organization, a literature survey had was conducted to identify publicized resources that could be used in academic research. As a result of this literature survey, an illustrative example is identified and presented in Section 3.1.

In order to complement the "product development assessment" at Tier-3 level, a representation of domain specific processes and a collection of relevant metrics were needed. In order to address this need, a literature survey was conducted. The process diagrams found in literature were used as a starting point and the detailed process diagrams was developed using an illustrative case. With similar challenges about accessing and using information in an existing organization, the use of illustrative examples for processes and metrics was preferred in order to illustrate the last step in an improvement initiative.

The research methods presented herein are shaped with the limitations on the use of commercially sensitive data. As a result of these limitations, the discussions about presenting the application of this framework primarily relies on published business cases, illustrative assessment results, and synthesized process structures and corresponding metrics.

3 Presentation of Framework

Many stakeholders of the organization may use performance assessment data. Business unit managers and managers use measures to evaluate productivity, efficiency and effectiveness of their business. Executives use measures to review how well corporate strategy is being implemented and whether major corrections in strategies is required. Shareholders and industry analysts use publicly available assessment results to make decisions such as whether to invest in or do business with a company. On the other hand, employees get feedback from assessments and learn whether they and their teams are contributing to company goals. Therefore, results of an assessment can be used in many ways by a variety of stakeholders. As discussed in Chapter 1, the scope of this work is limited to identification of performance gaps, and definition of relevant metrics for analyzing these gaps. This work suggests that, linking business improvement goals and relevant issues with processes and relevant metrics (Figure 28) is essential to the success of improvement intitiatives for all stakeholders.

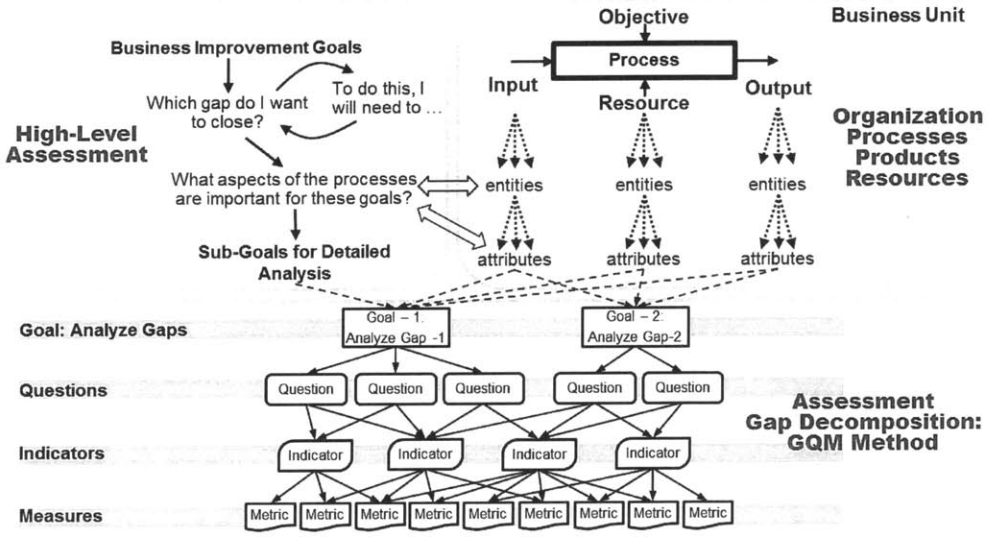

Figure 28 Integration of Business Improvement Goals, Business Processes and Metrics

The theoretical approaches introduced in Chapter 2 are useful in analyzing different aspects and characterizing the current state of business. However, in many large organizations the biggest challenge is developing a self-assessment method which will be practical to use for all these different purposes. Many downstream activities of the organization can be specific to the products and services. Therefore, it is not realistic to expect a high-level assessment to address the performance issues at all detail levels and be applicable to all kinds of businesses with specific processes. Once the high-level business problems have been identified, they need to be decomposed into specific issues and corresponding metrics for specific processes. In this chapter, a three-step approach will be demonstrated as shown in Figure 29. These three steps represent the flow of an assessment, starting from high-level business goals down to process specific metrics.

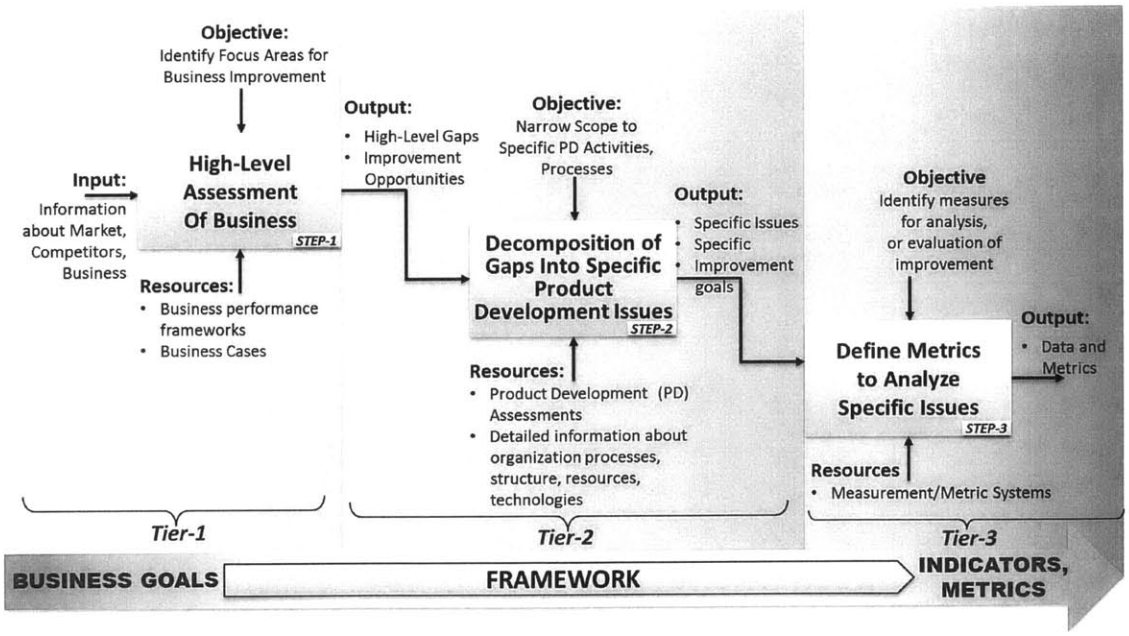

Figure 29 Selected Tools and Approaches for the Framework

A suggested PD assessment approach was discussed with subject matter experts (SMEs) and the content of the PD assessment questionnaire was validated using two

assessments which were performed in an existing business. Also, the additional feedback received from the SMEs was used to structure the steps of the framework. As discussed in '2.7 Research Methods' section, the initiative for performing a PD assessment is mostly triggered by business-level concerns. Therefore, an understanding of the business case in-hand is crucial in aligning the expectations from the PD assessment with business improvement goals. However, due to the commercial sensitivity of information about business-level analysis of an existing business, a publicized business case (Mills & Kurz, 2003) will be used. This case will be utilized to illustrate Step-1 which aims to identify the high-level improvement goals for a business. After completing our case discussion, we will focus on the identified improvement goals and present their use in transitioning to Step-2 by associating them with PD assessment questionnaire clusters. Once this link is established, the questionnaire will help us pinpoint specific gaps in PD. In Step-3, these specific gaps will be traced to related processes of an organization. Deriving new metrics or selecting the relevant ones that characterize the operations within a process will be the subject of Step-3. However, we would once more like to emphasize the fact that the illustrative examples do not reflect the situation in the real business case and do not use actual data collected from the sponsoring organization. The intent of using illustrative data is to be able to develop the content required to demonstrate the steps in the framework.

3.1 Step 1: High-Level Assessment of Business

In section 2.1 we introduced three important approaches which are instrumental in analyzing business performance. The performance dimensions addressed by these perspectives include 'customer', 'stakeholder satisfaction', 'market' and 'financials'. These factors are major elements that need to be incorporated into the high-level

assessment of a business. However, the prospects in which these factors influence overall business performance are highly dependent on the specific circumstances of the existing business environment. Therefore, we would refrain from suggesting the use of a specific approach for all cases. Instead, we would present a real business case and identify the high-level improvement goals identified by business leaders for this specific setting. These goals will be used for grouping PD related factors and enable us to demonstrate how an assessment can transition to looking at specific aspects of PD without losing connection with higher-level improvement initiatives.

3.1.1 Business Case for the Assessment

Siemens AG is a German multinational conglomerate company with activities in the fields of industry, energy and healthcare, headquartered in Munich, Germany[1]. It is organized into five main divisions: Industry, Energy, Healthcare, Infrastructure & Cities, and Siemens Financial Services (SFS). Siemens and its subsidiaries employ approximately 360,000 people across nearly 190 countries and reported global revenue of approximately 71 billion euros for the year of 2011[2].

Siemens has origins in Siemens & Halske which was founded in 1847 in Berlin, Germany, by Werner Siemens and J. Halske (Braun, 2004). The company consisted of a workshop to manufacture and install electrical telegraphic systems. Innovations such as the first electrically powered railway in 1879 and the first electric elevator in 1880 were the first success stories of Siemens after its discovery of the dynamoelectric principle in 1866. With these innovations the company quickly became a leading organization in the electrical engineering industry and by early the 1900s, the company was one of the

[1] www.wikipedia.org. July 2012. Retrieved 12 July 2012.
[2] www.siemens.com. July 2012. Retrieved 12 July 2012.

leading companies in the field. Siemens' innovative and successful operations continued throughout the 20th century. The company expanded its presence in the fields such as communications, electric power generation, lighting, household appliances, automotive systems, data processing systems, and semiconductors. In 1969, Siemens AG was formed by a merger, in order to give the company a stronger identity and market presence.

One of the main segments for Siemens' operations is healthcare. The history of Siemens Medical Solutions goes back to the RGS Company which was established in 1877. After the discovery of X-rays by Roentgen in 1895, RGS began manufacturing X-ray tubes and equipment. In 1925, Siemens & Halske became a majority stockholder and over time, the new medical arm of Siemens expanded with new innovations. Some of these innovations are listed in Table 5. In order to keep the pace of its innovations, the company maintained close relationships with the scientific community, conducting research and development (R&D) in cooperation with physicians, hospitals, and universities.

Date	*Innovation*
1896	Industrially manufactured X-ray tubes for medical diagnostics
1911	First electrocardiogram with electronic signal intensification
1913	First electric hearing aid worldwide
1956	Universal measurement system for nuclear medicine
1958	Implantable cardiac pacemaker developed in Sweden
1966	First ultrasound echography device with real-time display
1975	First instant image in computed tomography produced on a Siemens device
1982	Erlangen technicians install first Siemens magnetic resonance imaging system in US
1992	First digital network in a radiology department, installed in Vienna Hospital
1995	First Ultra-Fast Ceramic (UFC) detector
1999	Introduction of Syngo software platform for all product platforms and workstations
2002	First European installation of Biograph, a combined position emission tomography (PET) and computed tomography (CT) system

Table 5 Source: Adapted from B. Braun, "125 Years of Siemens Medical Solutions—Providing the Future in Healthcare," Siemens AG, 2002.

In the early 1990's, Siemens Medical became a global company with "product platforms" covering a wide range of imaging and other medical equipment, including angiography and X-ray, computed tomography, mammography, magnetic resonance imaging, electro medical systems, nuclear medicine, ultrasound, special workplaces, and oncology care systems. In contrast to the product divisions, which had global responsibility for their products, the sales and service organization was structured by region. Products, product groups and services of the organization are listed in Table 6.

Products	*Groups*	*Services*
Angiography	Cardiology	UPTIME Services
Computed Tomography	Neurology	IT Services
Fluoroscopy	Women's Health	Consulting Services
IT Solutions and Consulting	Oncology	Life
Magnetic Resonance	Urology	DICOM
Mammography	Orthopedics	
Nuclear Medicine	Molecular Imaging	
Oncology Care	Vascular Diseases	
Patient Monitoring		
Radiology		
Surgery		
Ultrasound		
Urology		
Ventilation and Anesthesia		
Accessories and Suppliers		
Refurbished Systems		

Table 6 Overview of Siemens Medical Business Areas and Divisions (Source: Siemens AG, Annual Report, FY 2000–2001)

3.1.2 Challenges for Business and Corresponding Business Improvement Goals

External factors and changes in the marketplace may impose challenges to operations of the businesses. For Siemens Medical Devices (MED), the external disruptions came from changes in behavior of health-care providers around the world and resulting changes in acquisition decisions in the health-care industry (Mills & Kurz, 2003). In the mid-1990s healthcare providers were continually challenged with trying to reduce costs resulting in

a change in the way they purchased medical equipment. The pressure to reduce costs shifted the primary acquisition expectations from devices with superior technical performance and quality to devices with the lowest price. These behavioral changes put the medical equipment industry in a state of overcapacity and eroded profit margins (Mills & Kurz, 2003).

In addition to the general challenges for the industry, competition in the healthcare market was also changing (Mills & Kurz, 2003). Before the 1990s several medical equipment providers were competing in the market, but due to the cost-reduction pressure and declining sales, several companies were closed and some others were acquired by larger companies. As a result of these mergers, competition became more intense and three major players emerged: Siemens, General Electric, and Philips. At those times, Siemens Medical had a significant cost disadvantage compared with its competitors. A large portion of this gap was arising due to the high costs of materials and manufacturing. When Siemens investigated the situation, the analysis showed that manufacturing overcapacity and overhead costs were higher than those of its competitors (Mills & Kurz, 2003).

In 1996 Siemens Medical recognized the fact that business results for the company were not acceptable and the situation was not improving. In that year, the profit forecasts for the organization were around €90 million; however a loss was likely in the practical situation. The organization decided that it needed to make dramatic improvements and set the company on a course for profitable growth. Siemens Medical started with a top-down approach to analyze the business and involved business leaders in this intensive effort. The strong initiative put in place for improving the business results identified three main objectives (Mills & Kurz, 2003):

- Identify new business opportunities and new product portfolio elements; adapt business goals to changes in market and customer behavior, expand into growth segments.
- Restructure the business; improve leadership quality to improve achieving goals, meet cost objectives by initiating design-to-cost projects
- Continuously improve operational efficiency; identify process improvements and improve product innovation, invest in human resource development

3.1.3 Importance of External Factors in Goal-setting

The selection of this business case is deliberate in the sense that, it represents a real improvement initiative which addresses all of the performance dimensions that we introduced in section 2.4.1 (see Figure 30). These three dimensions will be important to us when we introduce the 'questionnaire for product development assessment' in section 3.2. We will use the same dimensions to categorize the clusters in the questionnaire. Therefore, the elements in these clusters will serve as the decomposition of these high-level business goals into the domain of product development.

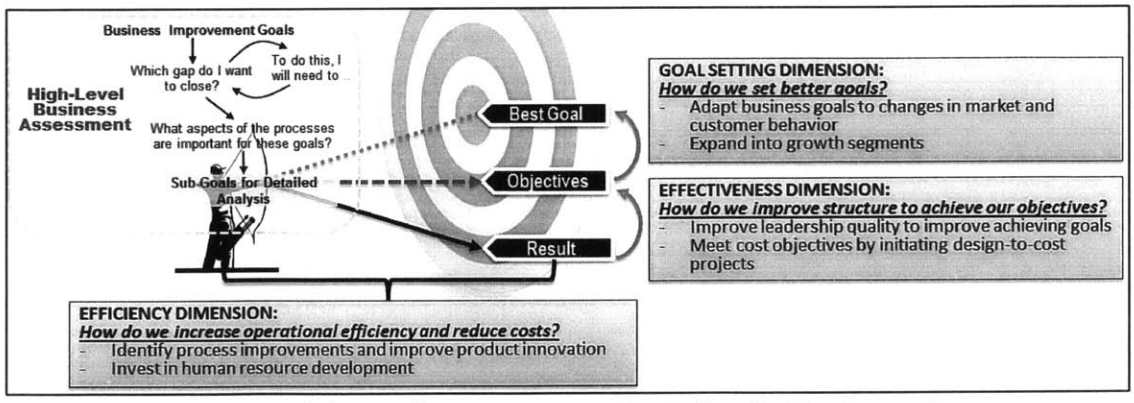

Figure 30 High-Level Improvement Goals for the Business-Case

Although we will use the 'assessment questionnaire' to help us in identifying the product development related issues corresponding to business goals, it is important to highlight the strengths and weaknesses of this approach. As presented in section 2.2, Figure 12; the assessment questionnaire is more focused on assessing the impact of internal factors and processes compared to assessing 'market strategy' and 'strategic goal setting' capabilities of the organization. This does not mean that 'questionnaire' ignores these aspects; some sections in the questionnaire (e.g. "strategy", "customer satisfaction") are used for assessing the organization in terms of its ability in responding to changes in external market conditions and strategic goal setting capabilities. Therefore, using the questionnaire it is possible to identify possible problems that may arise due to changes in external environment. However, knowing that 'organization has a problem in setting the right goals for the new environment' may not help the organization to define better objectives.

In most management literature, defining goals is referred to as the most unstructured and ad-hoc process (Chatterjee, 2005). In order to determine the new goals for the organization, it is necessary to understand its current position in the market and the possible ways through which it can increase its value proposition. This is one of the most important factors on the road to attaining better business results. As defining new strategic goals/ new markets/ new value propositions are dependent on the specific circumstances of business, this topic extends beyond the scope of this work.

As stated in our introduction to Chapter 3, this work does not recommend a specific method for the high-level assessment of business performance. Insights provided by executives, experience of senior managers or the findings of business performance management frameworks (e.g. BSC, SMART Pyramid which were introduced in

section 2.1) can be highly influential in the evaluations at this level. Although an application of a specific method is not included for demonstrating Step-1, the following paragraphs in this section are reserved for a brief discussion about how Siemens MED addressed the issue of 'setting goals' to respond to the changes in the external environment that it operates within.

In the "Goal Setting Dimension" the question in consideration is how to adapt business goals to changes in market and customer behavior. For MED, this required a new vision and strategy to drive business growth with choosing business objectives which are better aligned with the changes. For the company, this meant that its business focus had to change from individual medical equipment to integrated solutions. In other words, customer needs had to be understood better, and the corresponding portfolio of products and complementing services needed to be developed. In the real business case, these portfolio changes not only prepared the groundwork for MED's on-going transformation and a new market positioning, but substantially expanded the size of the company's addressable market.

> *"With these new service and IT offerings, MED started to fundamentally transform its value proposition. Rather than selling independent pieces of equipment, the company could develop and offer comprehensive solutions, covering a much broader range of its customers' needs. MED could advise customers on how to improve their processes and what equipment they needed, provide equipment across modalities, offer IT systems and IT integration services, and lastly provide ongoing customer service and support. With this new, IT-centered value proposition, MED offered customers a way to improve their clinical, operational, and financial performance." (Mills & Kurz, 2003)*

In addition to improving customer satisfaction, these new market segments, being better business goals aligned with new market conditions, grew significantly faster than the company's traditional market and improved the financial results as well. Therefore, it is clear that, in the real case, the company set better goals and achieved better business results.

Our key takeaway from the summary above is the importance of defining the functionality of products and services which can be a better fit for the changing market conditions and customer expectations. This observation is used for framing an example to illustrate a gap which can be identified by PD assessment questionnaire. In section 3.2, 'Defining Product's Functional Content' will be used as a high priority area in PD which requires further analysis in an assessment.

3.1.4 Process Improvement Related Aspects in the Business Case

As we discussed in the previous chapters, even if the goals are promising, the dimensions of effectiveness and efficiency are crucial in achieving these goals and realization of successful results. In these aspects, the company focused on a number of barriers or challenges including reluctance to change, adjustments to culture, functional vs. departmental thinking and fears of losing power. In order to address this, teams were implemented and charged with identifying and prioritizing areas of conflict, defining removal action plans, and implementing the transition. Also, efforts were spent in order to transition to a process-driven organization. Such a transition requires identification, standardization and documentation of processes of the whole organization.

At this point, it is important to distinguish the need for defining processes for the whole organization from the need for identifying specific processes that are

important for analyzing a specific issue. The first one requires extensive effort and serves a high-level business objective about transitioning to a process-driven organization. However, the second need can be satisfied by a much more limited effort focused on diagnosing the specific problem and the resulting process representations can be limited to the aspects which are relevant to the issue in-hand. These limited representations can be tailored subsets of the complete organizational process structure and cut across different activity domains. It is clear that, if the organization has already developed a very comprehensive and detailed process repository for activities of the whole organization, the effort for identifying issue-related ones will be significantly reduced.

In our framework, Step-3 requires the identification of processes for a specific issue. Therefore, this step will benefit from the data in the organizational process repository for the whole organization. With this insight, 'Siemens Process House', the organizational repository for the whole organization, is introduced at this step as a significant outcome of Siemens' high-level business goal of transitioning to a process driven organization. After identifying PD issues in Step-2, we will use this resource as a starting point to derive an issue specific process representation.

The 'Siemens Process House' covers all business activity domains such as: management, customer relationships, supply chain management, product lifecycle management and support processes. In open sources (Rohloff, 2009), the reason for developing the 'Process House' is not directly associated with the high-level business goals specified in the business case that we introduced in the previous section. However, we will use this process structure in section 3.3, as a depiction of top level of 'Siemens Process House' and start our derivation of the issue-relevant details of processes. Figure 31 represents the top-level which is composed of high-

level activities (macro-processes) of the whole organization. Within the hierarchy of the 'Process House', each activity has detailed decomposition of processes underneath the main activity.

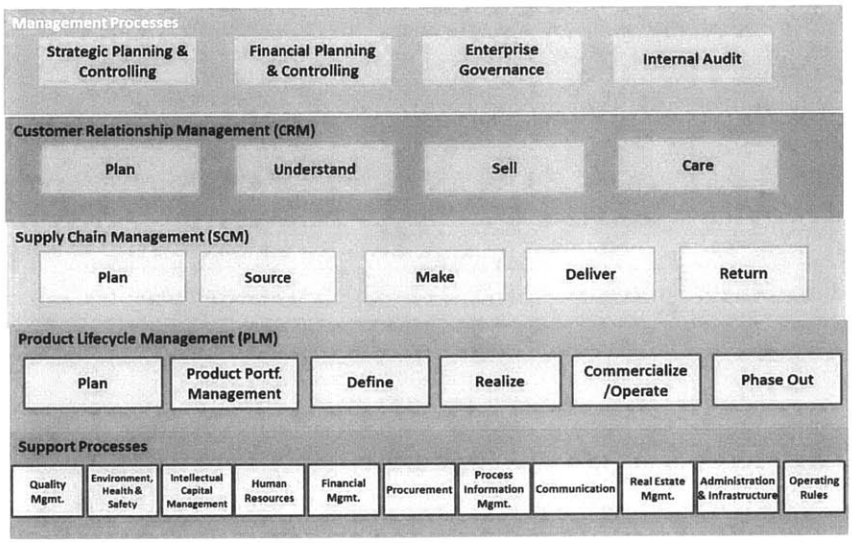

Figure 31 Siemens Reference Process House (Rohloff, 2009)

3.2 Step 2: Questionnaire for Product Development Assessment

In this section we will demonstrate Step-2 in the framework (see Figure 29) and use the 'Product Development Assessment' questionnaire categories to help us decompose business goals to smaller performance clusters. Therefore, the first task in this step is to associate PDSAT (Knoblinger, 2011) categories with the outcomes of Step-1. The categories of questions in PDSAT were introduced in Table 3. In Figure 32, each category is assigned to the corresponding business goal defined in our specific business case and in total they represent all of the different factors that contribute to the goal. Although the decomposition suggested herein is specific to the goals described in Step-1, the feedback received from SMEs about content and

categories of PDSAT validates its comprehensive coverage encompassing different sets of goals identified in real business cases. However, full validation of an assessment framework for all possible business goals is not a feasible objective for this thesis. In 'future directions' section, we will emphasize the importance of increasing the number of cases used to validate the framework and capturing the characteristics of these cases to build a guide that can be used to evaluate risks of using it in different settings.

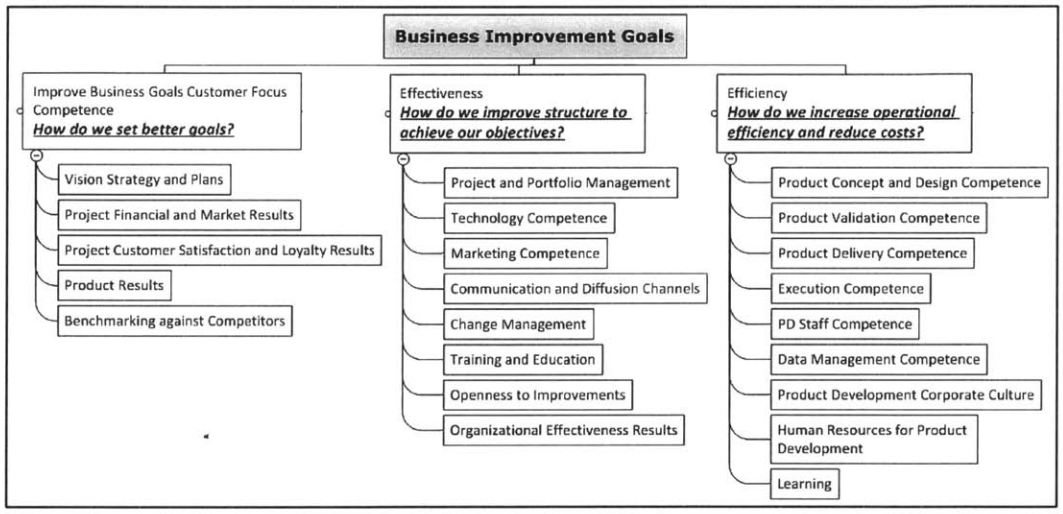

Figure 32 Decomposing Business Goals to PD Assessment Performance Clusters

Figure 33 represents this step within the overall framework. As seen in this figure, assigning questionnaire categories to business improvement goals provides the integration of Step-1 with Step-2 in the framework. Once this integration is done, it will be possible to correlate the results of the assessment questionnaire with the business improvement goals.

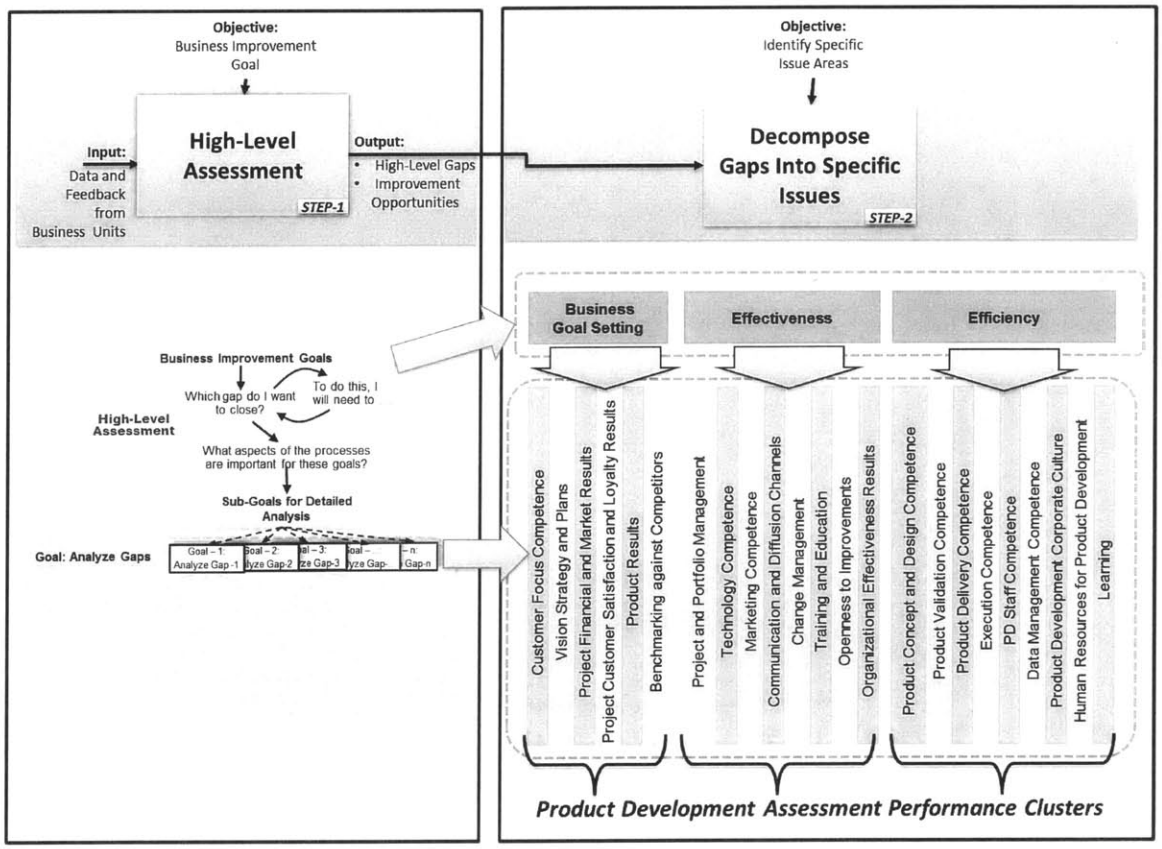

Figure 33 Second step in analyzing business issues with the suggested methodology

This approach introduces an interim step between the activity of 'identification of business goals for improvement' and 'assessing product development'. it may be helpful to perform the preliminary assessment at the aggregated categories level with the help of business unit leaders. This can provide an early picture of the current state and problematic categories related to product development can be identified. In addition, this initial screening would enable the assessor to prioritize his next steps and help to identify specific areas to focus efforts. The results of the initial screening using the PD assessment categories will yield results similar to those shown in Figure 34. The figures used in the charts are for illustrative purposes only and do not reflect the situation reflected in the business case that has been introduced previously.

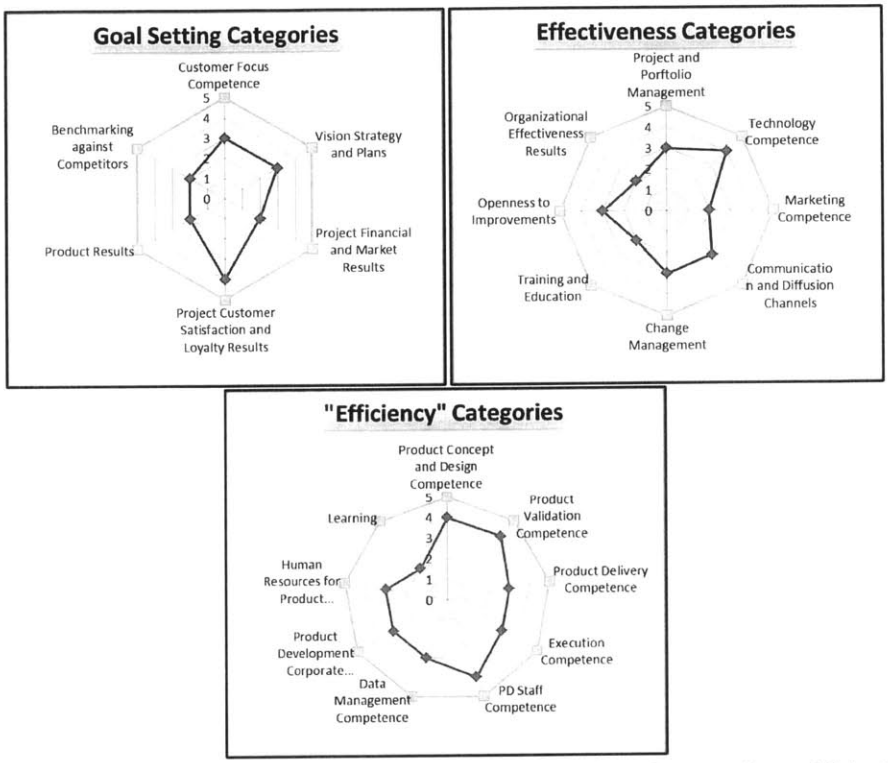

Figure 34 Illustrative Results for Initial Screening using Categories within Product Development Assessment Questionnaire

Once the preliminary evaluation is done, the next step is further diagnosis of specific issues within the areas of high-priority. In this work, we will use the PDSAT Questionnaire for further diagnosis and demonstrate decomposition of improvement goals into sub-issues. As shown in Figure 35, this constitutes the 2nd step in the suggested framework. However, it must be noted that, there will be multiple iterations of Goal – Question decomposition before the last step. In section 3.3 we will go through a similar exercise and derive a list of questions for a more refined set of gaps that are identified by the results of questionnaire.

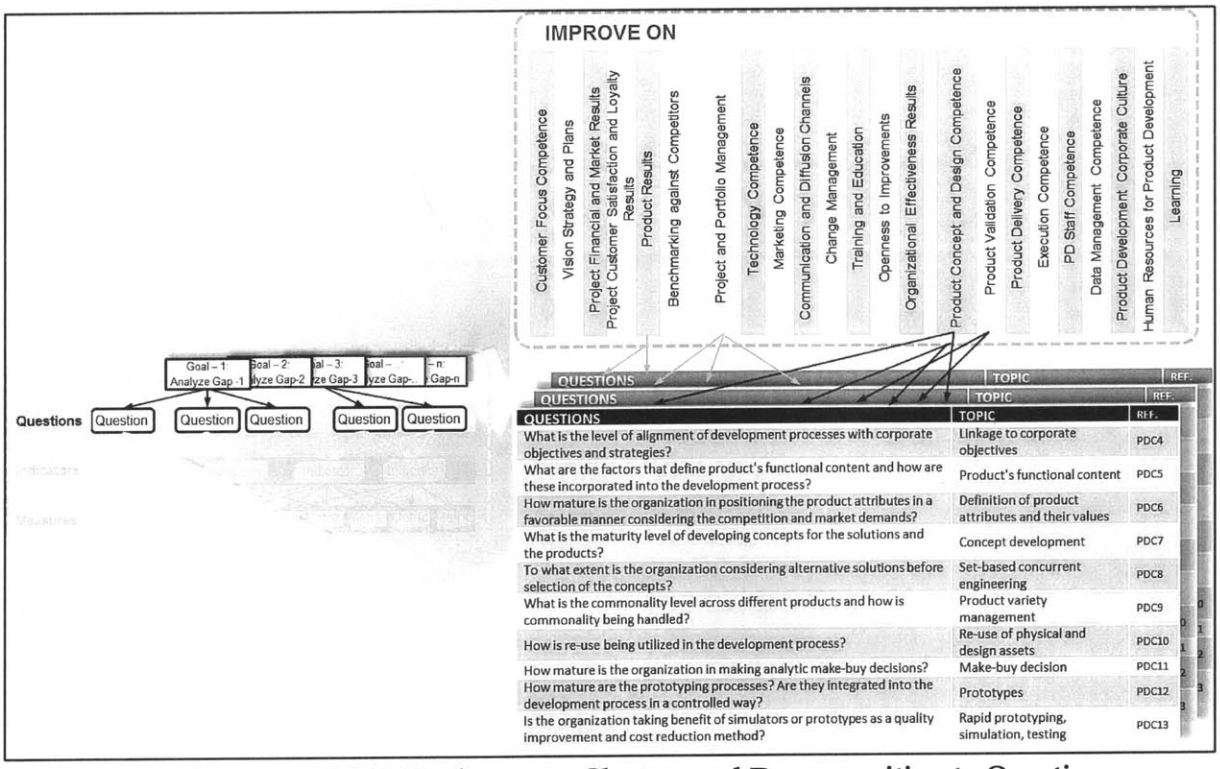

Figure 35 PDSAT Performance Clusters and Decomposition to Questions

In the PDSAT questionnaire, each performance cluster is further divided into topics which can be considered as success factors for product development. In the following table we will present some of these factors in the PDSAT questionnaire with their corresponding questions. In order to preserve the brevity of the tabulation, all of the PDSAT content is not included in Table 7. Except PDC5 and PDC6, which are related to our illustrative example, the rest of the items are selected randomly.

	Ref	Topic	Question Addressing Topic
Product	PDC3	Product architecture	What is the maturity of architecting processes in the organization?
	PDC4	Linkage to corporate objectives	What is the level of alignment of development processes with corporate objectives and strategies?
	PDC5	Product's functional content	What are the factors that define product's functional content and how are these incorporated into the development process?

	Ref	Topic	Question Addressing Topic
	PDC6	Definition of product attributes and their values	How mature is the organization in positioning the product attributes in a favorable manner considering the competition and market demands?
	PDC7	Concept development	What is the maturity level of developing concepts for the solutions and the products?
	PDC8	Set-based concurrent engineering	To what extent is the organization considering alternative solutions before selection of the concepts?
	PDC9	Product variety management	What is the commonality level across different products and how is commonality being handled?
	PDC10	Re-use of physical and design assets	How is re-use being utilized in the development process?
	PDC11	Make-buy decision	How mature is the organization in making analytic make-buy decisions?
Product Validation	PDC12	Prototypes	How mature are the prototyping processes? Are they integrated into the development process in a controlled way?
	PDC13	Rapid prototyping, simulation, testing	Is the organization taking benefit of simulators or prototypes as a quality improvement and cost reduction method?
.	...	...	...
Data Management Competence	PDC35	Use of project performance metrics	Is the organization making use of performance metrics and how mature is the process of turning these metrics into useful feedback for decision making?
	PDC36	Productivity metrics	Is the organization collecting measures and metrics related to productivity within the processes in Product Development domain?
	PDC37	System of data collection, management and usage	Is there a formal and established data collection and management mechanism to collect information related to Product Development?
	PDC38	Knowledge management system	What is the awareness of the organization in terms of 'knowledge management' and its integration with product development processes?

Table 7 A Subset of Product Development Competences Defined in PDSAT

In the PDSAT Questionnaire, for each topic, a set of indicators are developed in order to assist the assessor to assign a maturity level for the current state (description of maturity level indicators shown in Table 8 is a very small subset of the overall content). The descriptive text in each column may also serve as criteria that can be used in identifying a sub-issue. We will demonstrate the use of these criteria in section 3.3.

Product Concept and Design Competence

(PDC 3) Product architecture				
What is the maturity of architecting processes in the organization?				
Level-1	*Level-2*	*Level-3*	*Level-4*	*Level-5*
A standardized process for defining the product architecture is not performed at any time.	Consideration is limited to the single product.	There is a product architecture that considers future upgrades and derivative products.	Architectural integrity is enforced in product design and system validation. Architecture reinforces brand identity.	Architecture is a strategy issue determined by senior executives. Architecture addresses all key functions of the firm.

(PDC 4) Linkage to corporate objectives				
What is the level of alignment of development processes with corporate objectives and strategies?				
Level-1	*Level-2*	*Level-3*	*Level-4*	*Level-5*
Project's/ Program's/Product's benefits are not mapped onto quantifiable business goals and objectives.	Most of the project's/program's/product's benefits are vaguely mapped onto quantifiable business objectives and goals. Many inconsistencies remain with no plans for their resolution and are left to personal interpretation.	Many of the project's/program's/products benefits can be mapped onto quantifiable business goals and objectives. Remaining inconsistencies are known but avoided and deferred for later resolution (no comeback dates are defined).	Project's/Program's/Product's benefits are explicitly mapped onto key quantifiable business goals and objectives. Mission and goal inconsistencies are known and delegated with due dates for resolution.	All project/program/product benefits are explicitly and comprehensively mapped onto key quantifiable business goals, objectives, and business initiatives. Few and only trivial mission and goal inconsistencies remain open.

(PDC 5) Product's functional content

What are the factors that define product's functional content and how are these incorporated into the development process?

Level-1	*Level-2*	*Level-3*	*Level-4*	*Level-5*
The definition process of the product's functional content is based on extensions of existing products and customer complaints.	Process of defining the product's functional content is largely driven by extensions of existing products and customer complaints.	Process of defining the product's functional content is largely derived from extensions of current products and product family consistency. Known customer base and competitors shape the product's functional content.	Process of defining the product's functional content is driven by market segment needs, strategic positioning, architecture, and input from benchmarks. Use of repeatable methods is made to prioritize and determine value to customers and of the firm.	Markets new to the firm and to the industry shape product's functional content. Architectural advantages are leveraged. Functional content sets new level of competitive advantage.

(PDC 6) Definition of product attributes and their values

How mature is the organization in positioning the product attributes in a favorable manner considering the competition and market demands?

Level-1	*Level-2*	*Level-3*	*Level-4*	*Level-5*
The product definition and planning process does not follow any standardized approach.	Product definition process is dominated by current products, engineering feasibility, and costs.	Product definition process considers current products' strengths and weaknesses relative to its competitors' products.	Product definition process is based on consumer preference methods, such as conjoint studies, to select product attributes and their values.	Product definition process considers consumer preferences and EVA in their use environment. Specifications are validated with lead users and suppliers. Cost-benefit analysis is performed by using quantified value propositions and models.

(PDC 7) Concept development				
What is the maturity level of developing concepts for the solutions and the products?				
Level-1	*Level-2*	*Level-3*	*Level-4*	*Level-5*
The product definition and planning process does not follow any standardized approach.	Product definition process is dominated by current products, engineering feasibility, and costs.	Product definition process considers current products' strengths and weaknesses relative to its competitors' products.	Product definition process is based on consumer preference methods, such as conjoint studies, to select product attributes and their values.	Product definition process considers consumer preferences and EVA in their use environment. Specifications are validated with lead users and suppliers. Cost-benefit analysis is performed by using quantified value propositions and models.

Table 8 A Subset of PDSAT Maturity Level Descriptions (Knoblinger, 2011)

The questionnaire presented above will help the assessor in the course of this engagement, and the feedback from the interviews with key product development constituents will identify the problems that limit the business value through product development. An analysis of the feedback to the questionnaire and maturity level ratings for each topic will increase the assessor's understanding of these problem areas. For communicating the results with other parties, the questionnaire results can be visualized as shown in Figure 36. It must be noted that although these results are deliberately aligned with the findings described in the business case, the assigned rating level is illustrative and does not represent real data collected during the business case described in section 3.1.

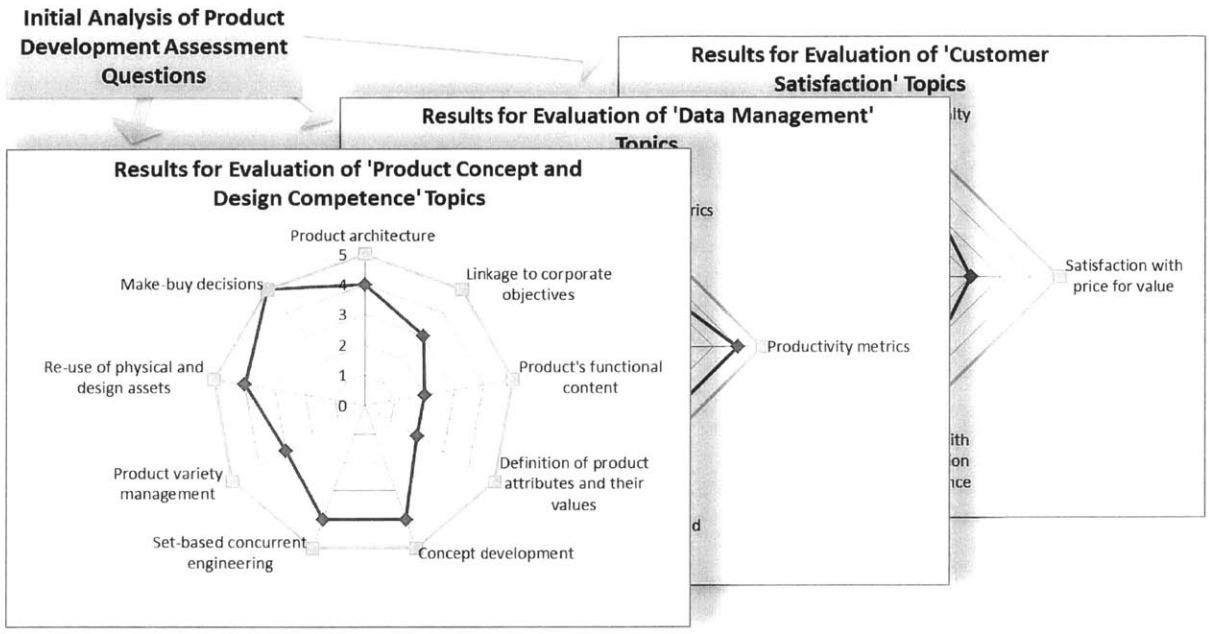

Figure 36 Illustrative Example of Results of 'Product Development Assessment Questionnaire'

Once gaps have been spotted and prioritized with the help of the questionnaire results, the analysis needs to further dive into mapping the cause-effect relations between the organization's processes and these gaps. The complexity of the organization's activities, typically illustrated by the long lead-time between activities and returns or the matching of inputs with outputs across different process areas (Kerssens-van Drongelen, Nixon, & Pearson, 2000) are factors which increase the difficulty of visualization of 'cause and effect relationships'. The large number of stakeholders involved in product development, often with various functional domains, result in a structural complexity difficulty. Therefore, even if a specific gap is identified, finding the corresponding activity and resolving the links to the root causes (human resources, technology, infrastructure etc.) can be challenging. In the next section, we will utilize the organization's processes to help us trace a specific gap to related organizational elements and processes.

3.3 Step 3: Defining Metrics for Case-Specific Diagnosis of Issues

Different literature resources from academia present generic views of the input-output connections between different processes contributing to product development and the interfaces between PD groups in the organization. Kerssens model is given in Figure 37 as an academic example of product development process representation. In this model, the author associates the 'product' with R&D Lab as an outcome of research and development activities. Therefore, if an issue has been identified in the area of "product function definitions" (as shown in Figure 36), this model refers us to the activities of the R&D Lab and lead us to analyzing its interfaces with 'marketing', business planning' divisions. This kind of guidance can be useful for further analysis of the issue and can help in identification of the relevant organizational elements.

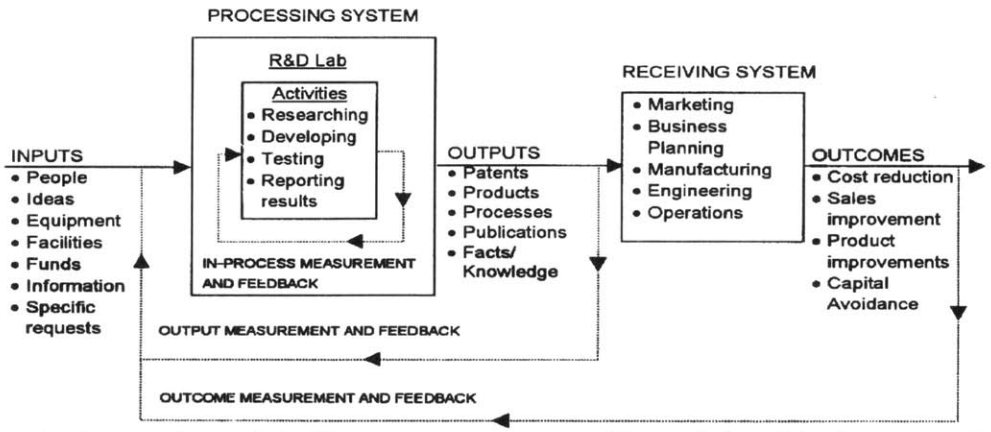

Figure 37 A generic model of input-output, cause-effect relationship for research and development (Kerssens-van Drongelen et al., 2000)

Despite the possible benefit of using such generic representations of product development, we would suggest the use of organization's own process structure (e.g. Figure 31) for further analysis of gaps identified by assessment questions. For the analysis of product development issues, it can be useful to refer to literature about a theoretical view of product development processes; however, if we need to investigate

the problems in an organization, we need to use (if it exists) or extract the process structure of the specific organization.

At this point, the reader should be aware of the difficulty in accessing representations of product development processes that are specific to an organization. A detailed process structure of an organization is generally considered to be part of its intellectual property and sharing this information is restricted. In rare cases, the top level processes are very generic and representations can be found in open literature (such as the one presented in Figure 31). With the difficulty of finding a detailed representation of company specific development processes, we would use Figure 31 as a starting point to demonstrate our approach. We are using this top-level view (sub-levels of Siemens Reference Process House is not available as a public resource) in the figure below, and tracing the gap to the corresponding process, which is shown as the 'define' block within product lifecycle management activities.

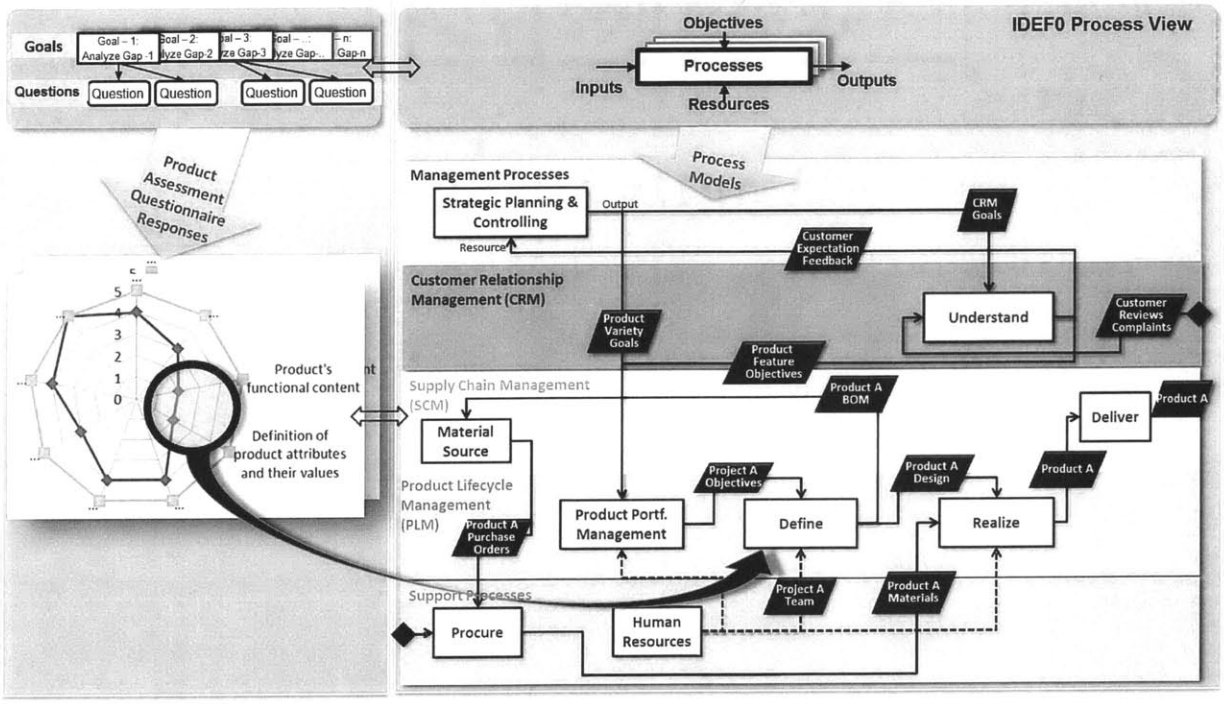

Figure 38 Associating gaps defined by questionnaire with top-level processes

In some of the organizations, existing process models can be very comprehensive and can cover all of the details of the important activities at lower levels. However, if this is not the case, the assessor can use some simple methods such as SIPOC (Suppliers, Inputs, Process, Outputs, Customers) (American Society for Quality, 2012) to extract the necessary information about the details of activities taking place under a specific process.

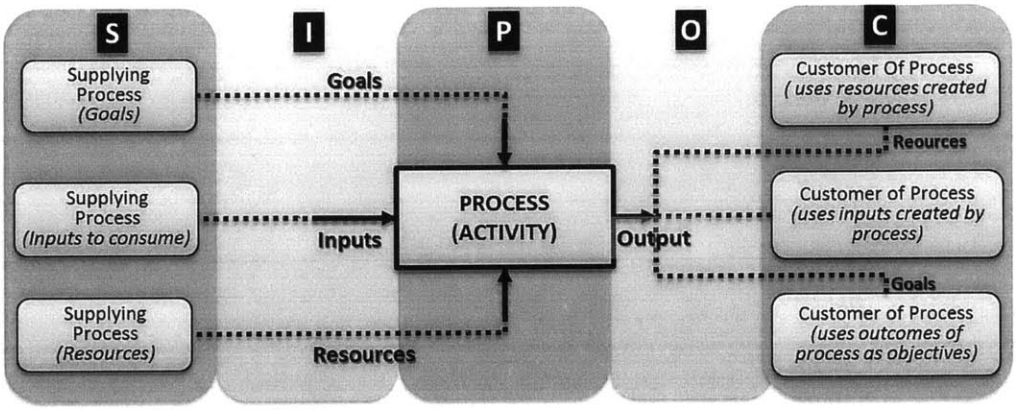

Figure 39 SIPOC Template for Extracting Details of Processes in IDEF0 Format

Within the scope of their use in this thesis, the 'supplier' and 'customer' in SIPOC model do not necessarily mean entities outside the organization, but they can also be considered as different groups within the same organization. During information collection with this template classifying the interface type as either one of 'goal', 'input', 'resource' and 'output' will enable construction of an IDEF0 model.

If the detailed process models do not exist or are not available, the assessor can ask questions to corresponding parties in the organization and extract a representative model of the activities. Within the scope of this work we have a similar limitation in accessing organization specific processes. The information in the table below is populated for illustrative purposes and intended to represent the data collected using

the SIPOC template. This information will be used to derive the detailed process structure under the "Define" block and enable us to analyze the issue further.

(S)upplier	(I)nputs	(P)rocess	(O)utput	(C)ustomer
•Project Management •Contract Management • Marketing •Product/portfolio management •Compliance and regulatory governance groups •Finance •Configuration Management	•Contractual Requirement •Customer Feedback •Product Family Functional Goals •Regulations and standards on product functions •Time and cost objectives	Define Product's Functional Content	•Functional Requirements •Product functional specs •Product concept •Functional Models • Decision tradeoff studies •Simulations and models •Product functional breakdown •Risk assessments •Functional Baseline configuration	•Product Design Groups •Project Management •Marketing •Product/portfolio Management •Procurement •Finance
•Configuration control board •Design Peer Review Groups •Project Management •Compliance and regulatory governance groups •Project Stakeholders, customer	•Change requests •Improvement action items	Revise functional needs and requirements / configuration management	•Revised functional baseline configuration	•Product Design •Project Management •Procurement
•Product/portfolio Management •Project Management •Marketing •Configuration control board	•Stakeholder attributes •Stakeholder prioritization •Constraints analyses, models	Analyze functional needs and requirements	•Revised functional configuration •Need-requirement allocation matrix •Platform architecture and reused functions list	•Product Design •Project Management •Marketing •Product/portfolio Management

Table 9 Example of data collection with SIPOC method

Using the information gathered by SIPOC method, corresponding detailed process structure is developed and presented in the following figure.

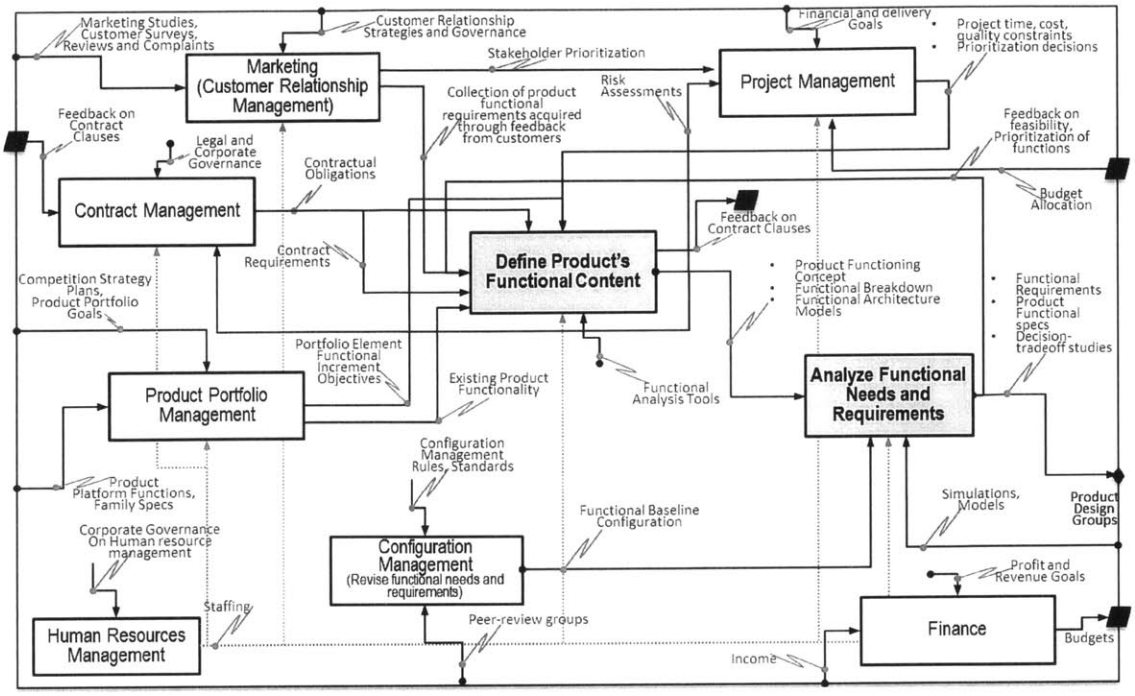

Figure 40 Illustrative IDEF0 Process Model Extracted with SIPOC Template

This process model contains the activities that are related to the gap identified by the 'PD assessment questionnaire'. In our illustrative case, the assessment resulted in a gap about the deficiency in defining product functions. Using the SIPOC method, we have extracted the list of connected processes as well as their interfaces. At this point, we would use this information to help us identify the relevant metrics that correspond to the case under analysis. This constitutes the last step in the overall framework.

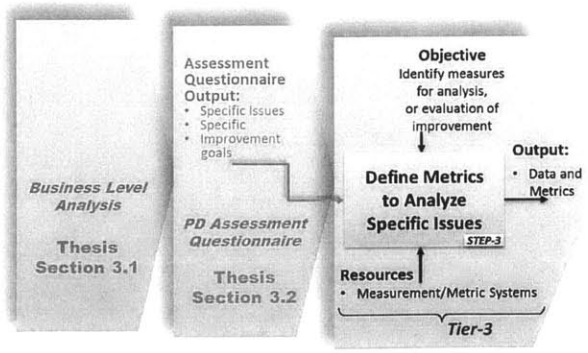

Figure 41 The last step in framework

3.3.1 Derivation of Metrics

In this last step, our intent is to specify the metrics that need to be collected in order to answer the questions addressing specific topics which are important toward closing the performance gaps. Previous paragraphs in this chapter were presented in order to demonstrate the preparatory activities for having the right process model ready before analysis. The captured process model is used as a guide for identifying the interfaces of the problematic process with different processes/activities within the organization. After this step, the assessor and the representatives of the processes need to work together in order to identify the best measures which characterize the performance of each process-to-process interface. These measures can already exist as well-defined metrics, or can be a combination of existing metrics. In this case, the scope of this activity reduces down to the selection and organization of existing metric information. However, in some cases, new measures may need to be defined with the help of business unit representatives. In either case, the process can be as follows:

- Trace the interfaces of the problematic process with other processes.
- For each process interface define the type of input (e.g. objective, resource) and the entity that flows in that interface.
- Define the output of the interface that is related to the use/processing of the entity; therefore identify the conversion (e.g. 'customer need' objective is converted to 'functional requirements' by the define process).
- For each interface and each conversion, collaborate with business unit representatives in order to identify a measure which characterizes the value of the conversion (e.g. Percentage of customer's functional needs that are covered by functional requirements in the baseline (per customer).

The table below is populated in order to present an illustrative example for the metric collection process by using the interfaces identified in the IDEF0 process structure (see Figure 40).

Process Interface	Specific Question	Id.	Metric for Analysis
Marketing, Customer Relationship Management ⇳ Define Product's Functional Content	How do we ensure that expectations of all customers are covered by product functions?	M1	Percentage of customer's functional needs that are covered by functional requirements in the baseline (per customer)
	How dynamic are we in adapting to customer's functional expectations?	M2	The number of new functional needs incorporated into product's functional baseline compared to the total number of new functional needs addressed during development
	How efficiently is CRM being employed in development?	M3	Percentage of product functionality design decisions made using CRM feedback
	Are market demands being addressed in defining functionality of the product?	M4	Number of product functions defined in response to a market/industry analysis report?
	Are customer satisfaction and feedback being considered in early stages of defining product functionality?	M5	Number of functional requirements derived using early feedback from customer or customer surveys
	Are product function definition teams effectively communicating envisioned product functionality with the customers?	M6	The number of product functionality demonstrations/presentations to the customer
	Is customer's opinion about the functionality of competitive products being used?	M7	The number of benchmark reports/studies used before base-lining product functionality
Product Portfolio Management ⇳ Define Product's Functional Content	Are the product portfolio goals and plans effectively implemented?	M8	Percent of defined product functions compared to planned functionality for portfolio element
	Are we utilizing existing portfolio?	M9	Percentage of functional commonality between members of product families
	Is the product differentiation rationalized?	M10	Percentage of new functions rationalized by product portfolio plans/objectives
	Is the existing portfolio contributing to efficiency of development?	M11	Percent decrease in man x hour for defining requirements for reused functions compared to original effort
	Is the additional functionality effective on business results?	M12	Revenues generated by the increased functionality product versus the revenues of original portfolio element
	How efficient is the interface between portfolio management tasks and product definition tasks?	M13	Man x hour spent with portfolio management group per issue resolved
Contract Management ⇳ Define Product's Functional Content	How do we ensure that contractual requirements are covered by product functions?	M14	Coverage percent of contractual clauses on defined product functionality
	Is contract management incorporating early feedback from product function definition tasks?	M15	Percentage of contractual clauses agreed by product function definition teams before contract is signed

Process Interface	Specific Question	Id.	Metric for Analysis
	Is the contract being managed according to change requests arising from functional analysis tasks?	M16	Percentage of agreed contract clause changes initiated as a result of change requests arising from functional analysis tasks compared to total number of requests
	Are the contract regulations being analyzed for implicit functionality requirements?	M17	Number of defined functional requirements tracing to contract clauses that implicitly address functionality
	What is the efficiency of the collaboration between contract management tasks and product function definition tasks?	M18	Average man x month cost of resolving a contractual issue related to product functionality
	How effective are product function definition tasks in achieving a successful contract execution?	M19	One minus the percentage cost of functionality waivers, changes compared to total contract price
Project Management ⇳ Define Product's Functional Content	Are project planning tasks incorporating feedback received from the results of activities on product function definition?	M20	The percentage of milestones agreed by product function definition teams before initial schedule baseline
	Are the project plans made considering the effort on function implementation?	M21	For critical product functions, man x month estimate in baseline project plan compared to estimates given by product function analysis teams
	Is project management providing feedback efficiently?	M22	The number of decisions made on functionality using feedback from project management compared to open issues awaiting feedback
	Is project risk management actively monitoring issues about product functions?	M23	The percentage of product function related risks that have mitigation plans
	How effective are product function definition tasks in creating successful project results?	M24	Percentage of deviations in project plans due to immature definition of product functions compared to the total number of deviations
Configuration Management ⇳ Define Product's Functional Content	How efficient is configuration control activities?	M25	The cycle time for functional configuration updates
	Are configuration management activities starting in early phases of product definition?	M26	The number of version updates on product function related documents before the initial baseline
	Is configuration change management incorporating feedback from all relevant groups?	M27	The coverage of groups which take part in configuration control board activities

Table 10 Questions and Metrics for Detailed Analysis of the Issue Identified by Product Development Assessment Questionnaire

With this step, 'the deficiency related to defining product's functional content' is decomposed into specific questions and quantifiable metrics that enable collection of data for further analysis. Considering the possible complexity of interaction between processes and activities, the task of identifying all related metrics can be exhaustive in a real scenario. Therefore, the time and effort required for performing a complete analysis

and identification all of the relevant metrics may not be practical. However, the awareness of the results of previous steps (Step-1: High-Level Business Goals, Step-2: Product Development Assessment Questionnaire) will provide a holistic perspective of improvement initiative and help the assessor in prioritizing specific processes (or interfaces) to focus on. This will also reduce the number of metrics that need to be analyzed. In order to support this idea, we will revisit Step-2 and recall the rationale of focusing on the gap that is related to defining product's functional content. In Step-2, the product development assessment questionnaire was used and the organization was rated with the criteria presented in the following question.

(PDC 5) Product's functional content				
What are the factors that define product's functional content and how are these incorporated into the development process?				
Level-1	*Level-2*	*Level-3*	*Level-4*	*Level-5*
The definition process of the product's functional content is based on extensions of existing products and customer complaints.	Process of defining the product's functional content is largely driven by extensions of existing products and customer complaints.	Process of defining the product's functional content is largely derived from extensions of current products and product family consistency. Known customer base and competitors shape the product's functional content.	Process of defining the product's functional content is driven by market segment needs, strategic positioning, architecture, and input from benchmarks. Use of repeatable methods is made to prioritize and determine value to customers and of the firm.	Markets new to the firm and to the industry shape product's functional content. Architectural advantages are leveraged. Functional content sets new level of competitive advantage.

Table 11 Assessment Question Used in Identifying the Major Gap

As seen in Figure 36, the rating that was assigned to the organization was Level-2. This was one of the lowest ratings and as a result the focus of the assessment was directed towards the topic defined in this question. This evaluation result also meant that the criteria stated in Level-3, 4 and 5 was not satisfied with the current state. With this information, the assessor already had an understanding of what the organization is not good at before starting to analyze specific processes and metrics at Step-3.

The organization is already good at... (using criteria specified in Table 11, Level 1-2)	The organization is not good at ... (using criteria specified in Table 11, Level 3,4 and 5)
• Effectively using existing product information in defining new product functionality. • Incorporating customer feedback/complaints into the activity of defining functional requirements.	• Using competitor related information and benchmarks to address required functionality. • The entire customer base is not used in defining functional content. • Market segmentation and product positioning are problematic. • Prioritization of functions by analyzing value to the customer is problematic. • Changing market needs and reshaping in industry is not being addressed in defining product functionality.

Table 12 The Insight about Organization's Deficiencies before Step-3

With the preliminary insight obtained from the product development assessment questionnaire, it is possible to narrow the scope of analysis that need to be done in Step-3. The preliminary insight, given in Table 12, point at the activities of 'customer relationship management', 'market analysis' and 'product segmentation within portfolio management'. Therefore, the assessor can focus on these activities, narrow the scope of detailed analysis of processes and as a result reduce the number of relevant metrics from 27 down to 12. The reduced set of questions and metrics is given in Table 13.

GQM			
Assessment Goal	Specific Question	Id.	Metric for Analysis
The entire customer base is not used in defining functional content.	How do we ensure that expectations of all customers are covered by product functions?	M1	Percentage of customer's functional needs that are covered by functional requirements in the baseline (per customer)
	How dynamic are we in adapting to customer's functional expectations?	M2	The number of new functional needs incorporated into product's functional baseline compared to the total number of new functional needs addressed during development
	How efficiently is CRM being employed in development?	M3	Percentage of product functionality design decisions made using CRM feedback
	Are product function definition teams effectively communicating envisioned product functionality with the customers?	M6	The number of product functionality demonstrations/presentations to the customers

GQM			
Assessment Goal	Specific Question	Id.	Metric for Analysis
Changing market needs and reshaping in industry is not being addressed in defining product functionality	Are market demands being addressed in defining functionality of the product?	M4	Number of product functions defined in response to a market/industry analysis report?
	Is customer's opinion about the functionality of competitive products being used?	M7	The number of benchmark reports/studies used before base-lining product functionality
Market segmentation and product positioning are problematic.	Are the product portfolio goals and plans effectively implemented?	M8	Percent of defined product functions compared to planned functionality for portfolio element
	Is the product differentiation rationalized?	M10	Percentage of new functions rationalized by product portfolio plans/objectives
	Is the existing portfolio contributing to efficiency of development?	M11	Percent decrease in man x hour for defining requirements for reused functions compared to original effort
	Is the additional functionality effective on business results?	M12	Revenues generated by the increased functionality product versus the revenues of original portfolio element
	How efficient is the interface between portfolio management tasks and product definition tasks?	M13	Man x hour spent with portfolio management group per issue resolved
Prioritization of functions by analyzing value to the customer is problematic.	Are customer satisfaction and feedback being considered in early stages of defining product functionality?	M5	Number of functional requirements derived using early feedback from customer or customer surveys

Table 13 Reduced set of Goals-Questions and Metrics

This reduction is a key benefit of using the integrated approach suggested in this thesis. In our discussion about the GQM method, we identified the most outstanding weakness of GQM was the risk of identifying more metrics than needed. With the insight provided by the product assessment questionnaire results, the scope of processes to be analyzed and the number of metrics to be derived can be kept at practical levels. We can extend this argument to the overall integration between the steps in the framework; the integrated use of methods at each step will help the assessor in making informed decisions about reducing the scope of analysis in the next step and focus on aspects that

are most important for the improvement initiative. Such a reduction in the amount of effort and time required to evaluate problems can be crucial in the success of improvement initiatives. Especially in the case of using external consulting, reduction in the costs of engagement and the use of consultant's time can be factors which determine the feasibility of the project.

3.3.2 Concluding Remarks for Framework Presentation

With the definition of specific metrics for our illustrative case, we arrived at the results defined as the outcome of Step-3 which also defines the boundary of this work (see Figure 2). The activities about data collection and intervention planning are not included in our assessment framework.

Due to the extensive scope of implementation steps of the framework, the presentation was distributed into the three sections of this chapter. However, in order to clarify the mapping between 'overall framework', 'implementation steps' and 'illustrative examples of results' that were used in this chapter, we would provide a visual representation of their linkage in Figure 42

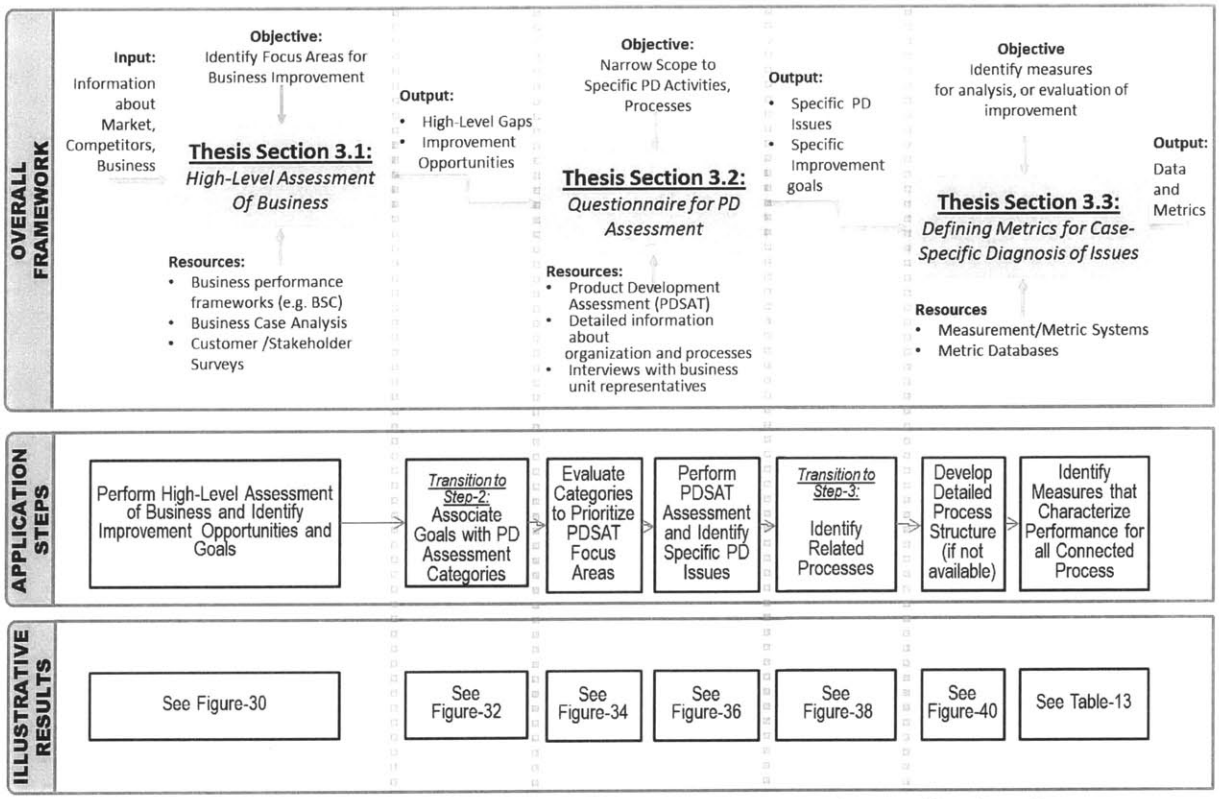

Figure 42 Visual Representation of Mapping between Framework, Application Steps and Illustrative Results used in Chapter-3

Although the collection of metric data and analysis of data for planning interventions is left out of the scope of this work, we would like to conclude this chapter by revisiting the recommended steps in the GQM method (See Figure 43).

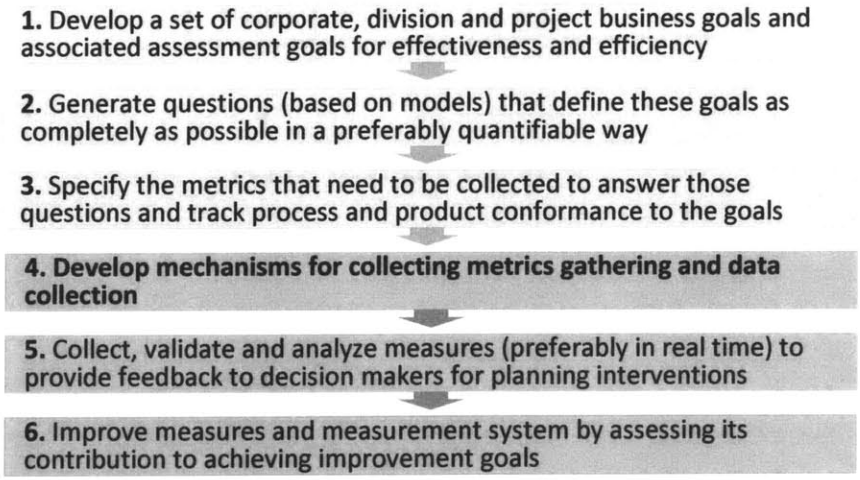

Figure 43 Goal-Question-Metric Steps in Assessment System Implementation (Repeated)

As seen in this figure, specifying the metrics that need to be collected for analysis of conformance with improvement goals is the outcome of the 3rd activity in the GQM process which is also the final step in our framework. The following activities are about the development of mechanisms to collect these metrics, validation and analysis of metrics and planning of interventions that would improve these measures. These activities are not included in this work. The information, gathered up to this point, is expected to constitute a satisfactory basis for data analysis and intervention planning. Therefore the assessment can be finalized at this stage and metric data collection can be started. However, at this point we would like to highlight the importance of establishing a mechanism for continuous collection of these metrics, preferably in real-time. It is possible that the improvement goals in an assessment may be satisfied with a single intervention that is based on an analysis that is done only once with manually collected metrics. However, even in this case, it is important to implement a solution that will be added to the organizational knowhow and be repeated when necessary. Therefore, capturing the evaluations and decisions made during assessment steps as well as implementing a mechanism that will continue to update the metric data even after the

resolution of issues is crucial in creating a learning organization. The issues in product development have big impacts on business results. In addition, the costs of improvement initiatives and assessments are high. In order to prevent the re-occurrence of the same issues and to avoid recurring assessment costs, a learning organization must pay attention to the 4th activity in GQM method. This topic will be discussed further in the last chapter of this thesis as part of future direction.

4 Conclusions and Future Directions

In this thesis, we started our discussion with the following statement:

"Self-awareness is an indication of intelligence for entities, which have capacity to evaluate and compare own behavior to internal standards and values. This property is very critical for adaptation to changing environments, as well as for being able to improve."

Assessments are tools to develop self-awareness in an organization. Throughout the chapters of this work, we attempted to develop a framework which can be used to create a top-down awareness of performance problems, starting with assessment of high-level business goals down to probing the details of operational processes within an organization. This awareness can help the organization to adapt to changing market conditions by defining more valuable objectives to direct its new businesses as well as to restructure its operations for eliminating deficiencies that limit its abilities to achieve its business goals at lower costs.

Despite the limitations in accessing real-data for use in demonstrating our assessment framework, we presented the flow of framework steps using illustrative examples and highlighted the importance of using them in an integrated fashion to be able to make informed decisions and to keep the scope of analysis focused by using the insight gained in the previous steps. In our presentation of an illustrative application of the assessment framework, the change in market conditions imposed a need for a re-definition of products and services created by the organization. The results of PDSAT identified a high-priority improvement opportunity in the way the organization defines its products and their functions. The structure of the processes that take part in defining product functionality were captured and depicted in a model. Using this model as a guide, the measures which characterize the performance of this structure were defined.

However, in our illustrative example, we used only one question in the 'product development assessment questionnaire' and demonstrated the way to break-down the issue down to corresponding metrics. The PDSAT questionnaire is a comprehensive assessment tool for identifying the gaps in product development domain. In the following section, we would discuss the limitations in our discussion and define the future directions in which organizations can take benefit of this tool when used in an integrated way as described throughout the chapters of this work.

4.1 Future Directions

In an attempt to use this framework in a real case, there may be many gaps that need to be analyzed and the scope of activities related to the issue can be very large. Such a situation may also result in an overflow of metrics that need to be derived or collected. Therefore, at this point, we would like to highlight two important limitations of the content provided in this thesis. The first one is the breadth of examples used to demonstrate the use of the framework. With the use of a limited number of illustrative examples, it is not possible to assert that the framework is fully validated for real environments. A future direction for this work is to pursue practical validation of the approach with examples and feedback received from real applications. Although it is likely not possible to share real assessment results of businesses in a publicized work, the insight gained from these real cases can be used to collect information about the characteristics of the issues for which the use of framework was successful. The addition of this information will be highly beneficial for potential users of the framework in evaluating the risks of using this approach for analyzing issues with different characteristics.

The second limitation of the approach presented in this work is the feasibility of using the framework when a large number of issues are identified in one step. As each step decomposes an issue into a multiple of sub-topics for analysis, the amount of effort required to implement the framework increases exponentially with the increasing number of gaps. In order to take the full benefit of using the framework, all of the relevant metrics need to be identified at the last step. However, when there are a large number of processes which are relevant to the issues, it may be infeasible to derive all of the corresponding metrics or to collect metric data for analysis. A potential solution can be the use of information and metrics gathered in previous assessments. Reuse of knowledge about methods, evaluations and results of previous assessments can also help in narrowing scope of analysis. In the next paragraph, we would generalize this problem to a broader context and present a brief discussion about the importance of 'organizational learning' and 'information systems' for such problems.

Even for a highly intelligent entity, full resolution of a complex issue that has been encountered for the first time may take a lot of effort. The strength of assessment/diagnosis methods used by the entity can be insufficient in limiting the amount of information that needs to be analyzed and reducing the time required for resolving the issue. However, the capability of learning, using previous experiences, and establishing efficient mechanisms for collecting diagnostic data can be useful in remedying this deficiency.

These aspects are also important for business intelligence and covered under the topics of 'knowledge management' and 'organizational learning'. Despite the vast amount of literature resources in these subjects, we would like to review one fundamental perspective and relate it to our discussion. A very special management thinker, Russell

Ackoff, addresses the elements of organizational learning and knowledge management in his depiction of an intelligent management system.

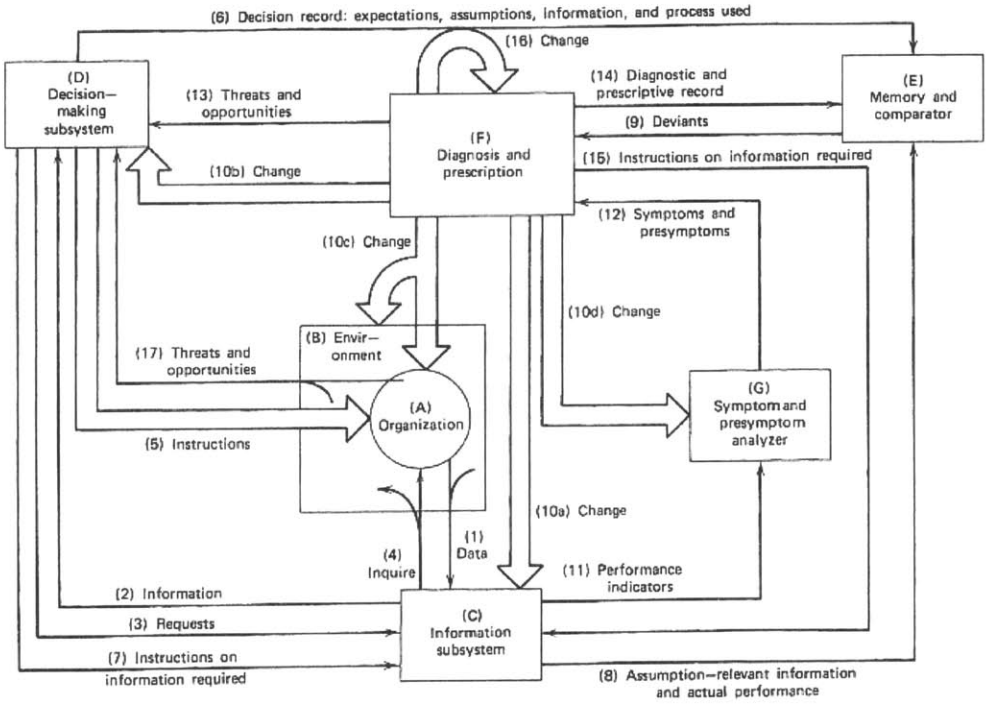

Figure 44 Diagrammatic Representation of a Management System (Ackoff, 1999)

In this representation, block (F) stands for the 'assessment' and 'intervention planning'. The results of the assessment are used by decision –making subsystems (D). However, there are three additional blocks – (E),(C) and (G) –which provide the critical information needed by 'assessment' and 'decision making'. 'Memory' and 'information subsystem' blocks provide the capabilities of; serving performance indicator and metrics for assessing symptoms and storing assessment records in organizational memory. These capabilities are very much aligned with the intentions of 4th, 5th and 6th tasks in the GQM method (see Figure 43**Error! Reference source not found.**) which were kept out of the scope of this thesis. With this observation, a future direction for this work is to develop practical and efficient mechanisms for implementing 'organizational memory

for assessments/assessment data', as well as to devise the corresponding information systems that help retrieval of stored information to enhance learning. Additional work in this direction can provide a solution for the 2nd limitation in applicability of the approach presented herein, by reducing the effort required for a full implementation of the steps in the suggested framework.

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