Towards a More Structured Goal Definition and Prioritization Approach for an Effective Measurement Process

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ABSTRACT

Measurement processes are vital for any organization as they are used to assess, analyze, monitor and control the processes, products and resources. The measurement programs are used in different ways in different organizations. Most of the measurement programs fail to provide the expected results; therefore it’s needed to consider the success factors and reasons of failures for the measurement programs. The GQM is the most widely used model for measurement programs having various extensions to overcome its shortcomings in different scenarios. The Goals, Questions and metrics are defined and used in different ways at different levels in the organizations. There is a need of improving the measurement programs and one of the solutions is to provide a framework that can define the goals, questions and measures in a structured way. The prioritization, traceability and re-usability of goals and questions provide the effectiveness in the measurement program. The optimization of the measures and building a measurement repository makes the measurement collection process precise.

In this thesis, the results of a systematic review on the current literature on software measurement programs are presented. An assessment of the current state of art on measurement programs, their usability and success factors is done. The study of measurement models, frameworks, tools and standards is done later on to know the different ways of goals, questions definition and measurement collection methods. The systematic review of the research work is done over the period 1997 – 2009.

In order to understand and explore the difficulties in application of measurement programs in the industrial settings, interviews are conducted within a CMMI Level 3 company.

On the basis of the systematic review analysis results and industrial interviews, a framework for a more effective measurement process is defined and within the framework, a model called ‘Structured Prioritized Goal Question Metrics (SPGQM)’ is developed. This framework extends the well-known Goal Question Metric paradigm and basically comprises of two models; the Optimum Measures Set Decision (OMSD) model developed within a Master of Science thesis study at the Blekinge Institute of Technology and the SPGQM. This framework defines the process in order to define structured goals and questions with the help of templates and to prioritize them with the help of OMSD model. This framework has been validated in a CMMI Level 3 company. The validation was done by means of conducting a case study.

Keywords: Measurement program, Structured Goal Definition, Structured question definition, Systematic review, Goal Based Measurement, Goal Question Metric, Optimum Measures Set Decision Model, and Goals Prioritization.
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1 INTRODUCTION

Software engineering organizations initiate measurement programs to create a corporate memory which can be used to understand, control, assess and improve their processes and products. However, most of these organizations have difficulties in deciding which measures to collect since there is no universal set of measures for all types of organizations and projects.

According to [3], most of the software measurement programs fail after implementation in software industry due to lack of appropriate knowledge of required measures. Experience shows that measurement programs can be more successful if measures are collected based on the goals of organization and/or projects. A few methodologies, models and techniques were developed to aid the software organizations for choosing the right measures (see section 2.3.2).

Goal Question Metric (GQM) [5] is one of the most widely known and used approach developed by Basili and Weiss. The GQM is a top-down approach in which specific goals are defined at conceptual level, then questions are asked that can answer the degree of achievement of goals at the operational level and at the last level i.e. quantitative level, metrics are defined to provide the quantitative and qualitative answers of the questions. The relationship between the questions and metrics can be one-to-one, one-to-many or many-to-many. However there is a need to improve the measurement process when there is difference between expected outcome of the process and the actual performance of the process.

In order to improve the measurement program and make it more effective, there is need to define structured approach for goal definition, question definition and prioritization. According to [13], there is a need for mechanism that guides in structured definition and prioritization of goals in a measurement process. Moreover, there is a need for a way of selecting the appropriate number of measures based on the prioritized goals.

There is also another constraint for the organizations: collecting measures cost. Therefore, software organizations also require selecting the minimum set of measures by prioritizing them based on the importance and priority of the goals of the organization as well as the cost associated with measurement to help achieving those goals.

A model called Optimum Measures Set Decision Model (OMSD) [46] was developed in the Blekinge Institute of Technology. OMSD is based on a heuristics approach, which aims to provide optimum set of measures from a general set of measures based on a number of factors such as time, cost, priority, value, type, and repetition.

However, although some good approaches have been developed to aid in improving the measurement process in organizations, a holistic approach with structured goals definition and prioritization processes is required. There is no standard way of defining the structure, quantity and syntax of goals and questions. This is important for tracking of goals, questions and measures and prioritization.

In this thesis, we propose a model, called Structured Prioritized Goal Question Metrics Model (SPGQM), an extension of GQM approach. SPGQM was developed to be integrated with the (OMSD) model.
1.1 Purpose of the Thesis

In this thesis, our purpose is to define a structured goal definition and prioritization approach which extends GQM and ‘Measurement Information Model’ [12], and integrated with OMSD model for a more effective measurement process. Our approach handles the dependency among goals, questions and measures [13] which is a requirement for goals and measures tracking, prioritization and deciding on the optimum set of measures (see chapter 3).

1.2 Overview of the Thesis

This dissertation is an investigation of current problems in software measurement programs and decision making on the basis of goal prioritization. The main objective of our research is to focus on the measurement problems and find the solution of more structured goals definition and prioritization approach for implementing effective measurement programs.

Our research work starts by the systematic review that involves the previous work done in the field of structured goals definition, question definition, prioritization among goals and questions for effective measurement program. In systematic literature review our focus was on:

- What is measurement program?
- Why do organizations need measurement program?
- What are the models, frameworks, tools and standards for measurement programs?
- What are the possible ways to define Goals and Questions and make prioritization on the basis of different factors such as time, cost, importance, value, type?

This research work proposes a model for structured goal, question definition and effective prioritization approach for a measurement program. GQM (Goal Question Metrics) and other models i.e. GAM (Goal Argument Model), GQIM (Goal Question Indicator Metrics), MPSP (Measurement Program Survey Package), MIM (Measurement Information Model) and Exploratory and Confirmatory Iterative Framework, is used as basis. This framework provides structured goals and questions definition and later on the goals will be prioritized (see chapter 3). The model development starts after systematic review and analysis the literature.

1.3 Background

In recent years, measurement programs assist a quantitative approach to development processes. These measurement programs also used in order to increase the software process improvement. Software measurement programs give a competitive advantage over those who prefer traditional approaches [15]. These programs have been an important part of software development life cycle (SDLC) like other processes i.e. design, testing, and implementation. Measurement activities are carried out during the software life cycle of project.

Software measurement programs help in both management and implementation of software processes at each level of the organization [3]. In order to get accurate results, it manages flow of data [4] within the processes. The software products are becoming larger and more complex. By managing such software projects require accurate and precise estimations that can be helpful to provide a quality product to the customer [2]. There should be a technological support and well defined structured approach to gather and process the data continuously throughout the software development. This process is called the measurement
process. This is used in the measurement program [3] which is basically a set of procedures and guidelines to gather, calculate and evaluate the measures.

According to [3], software measurement programs usually fail after implementation in a software development process. In [6], 50-80% of the measurement programs fail after an year due to different reasons. The most important reason of the failure of the measurement programs includes the lack of appropriate knowledge available to gain the required measures and/or too abstract goals [2].

The failure of the software measurement program depends on different factors relevant to product, process and resources [2], [3]. According to [11], software measurement programs usually fail as they require expert judgment for selecting appropriate number of measures in relation to the organizational goals. The mapping of goals with appropriate measures requires experienced resources in the field of software measurement. The goals are defined in order to satisfy organizational business objectives. These goals are required to be prioritized in an effective way so that the measures are selected accordingly.

The Goal Question Metrics (GQM) [5] is an approach that is most widely used to extract project, product and process goals from the business goals. These goals are defined at conceptual level which is mapped by a set of questions at the operational level. The selected set of measures is used to answer those questions. These measures are defined at the quantitative level of the GQM. The accurate estimation depends on all three above mentioned steps of the GQM [5, 27]. In ISO/IEC 15939 Measurement Information Model [12] specifies the steps that help in planning of the measurement program. The needed information is specified for the management and associated risks and problems with the measurement goals. One of the primary purposes of measurement in the software organizations is Software Process Improvement (SPI) [8].

There is a need to improve the measurement process; when there is difference between the expected outcome of the process and the actual performance of the process. In recent years, there are different models and frameworks developed that are used to measure different attributes of the software process. As stated in [7], Measurement Program Survey Package (MPSP) and Meta-Measurement Project (M2P) are the frameworks used to calculate the effectiveness of measures in a software measurement programs. The MPSP works in an organizational context and focuses on the research in order to identify the factors for the success of measurement program [3]. The M2P focuses on the measurement of the effectiveness of the measurement program and characterizing the quality of measurement objects [3]. In CMM [8] project tracking and oversight is used to measure the effectiveness of the software measurement program. The common attributes of measurement can be used to assess the novel Key Process Area (KPA) in the CMMI to measure and analyze measurement objects. The ISO/IEC 15504 software assessment standard provides the reference model to analyze the measurement process in terms of proposed outcome and best practices. This standard has two dimensions of measurement assessment i.e. purpose-specific and the process-generic [7]. In [9] assessment of the measurement program can be done according to different views i.e. process, product, resource, value based, context and social.

1.4 Thesis Structure

In this section, thesis structure is listed in tabular form. Following are contents of thesis according to each chapter.
Table 1.4: Thesis Structure
<table>
<thead>
<tr>
<th>Chapter No.</th>
<th>Chapter Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chapter No. 2 - Systematic Review</td>
<td>This chapter describes the planning of systematic review (section 2.1), conducting the review (section 2.2) and covers systematic literature review (section 2.3) linked with chapter 3, implementation of framework SPGQM.</td>
</tr>
<tr>
<td>Chapter No. 3 - SPGQM (Structured Prioritized Goal Question Metrics)</td>
<td>This chapter comprises the framework implementation on the basis of systematic literature review results. This chapter includes organizational perspective analysis (section 3.1), Structure goal and question definition phase (section 3.2 and section 3.3), post meeting analysis (section 3.4) and prioritization meeting (section 3.5).</td>
</tr>
<tr>
<td>Chapter No. 4 - Case Study</td>
<td>This chapter is about case study in an industry. In this chapter industrial interview are described. This chapter includes Case study design (section 4.1), case study conduct (section 4.2), SPGQM implementation (section 4.3), case study analysis (section 4.4), OMSD Implementation for reliability and maintainability (section 4.5, section 4.6 and section 4.7), effective prioritization by manager (section 4.8), goal and sub-goal prioritization (section 4.9).</td>
</tr>
<tr>
<td>Chapter No. 5 - Study Validation</td>
<td>This chapter consists of study validation after conducting case study. (Section 5.1) describes the types of validity threats that can occur during the whole thesis.</td>
</tr>
<tr>
<td>Chapter No. 6 - Epilogue</td>
<td>This chapter consists of conclusion, future research work and observations of authors are discussed. In Section 6.1 of this chapter some research recommendation along with conclusion are listed. (Section 6.2) consists of Future work.</td>
</tr>
<tr>
<td>Chapter No. 7 - References</td>
<td>This chapter contains references used in this research.</td>
</tr>
<tr>
<td>Chapter No. 8 - APPENDIX</td>
<td>This chapter includes different sections related to case study chapter. Section 8.1 describes the interview questionnaire, section 8.2 consist of goal, sub-goal and questions templates used in case study. Section 8.3 contains table regarding OMSD calculation and attribute factor mapping for both projects.</td>
</tr>
</tbody>
</table>
1.5 Research Questions

The research intends to answer these questions:

1. A) How Organizations use software measurement programs?
   B) What are the success factors in software measurement programs?
2. What are the models, frameworks, tools and standards for measurement programs?
3. What are the different ways to define questions/information needs in accordance to the measurement goals?
4. How does goal prioritization influence the measurement programs effectiveness?
1.6 Research Methodology

A mixed method research methodology [1] i.e. qualitative and quantitative is used in our research study. The qualitative analysis is used in order to examine the current research in software measurement field [1]. The qualitative data is assembled through literature study. Based on the qualitative analysis, a new approach will be defined. Quantitative analysis will be used for the evaluation of the new approach. It will be done by means of case study in an organization.

Figure 1.6: Research Methodology
1.7 Guidelines to the Reader

This section is about the guidelines to the intended readers

1.7.1 Audience
The project managers and measurement program personnel are target audience of this study.

1.7.2 Definitions

**Software Measurement Program/process** – It is set of task and activities to collect and analyze data to assess the maturity and areas of improvement in an object under study i.e. product, process and resource.

**ISO/IEC 15504** – consists of set of guidelines for the software process improvement areas.

**CMM / CMMI** (Capability Maturity Model® Integration) – the purpose of CMM and CMMI is to assess the maturity of software process and provide guidelines for improvement.

**GQM** (Goal Question Metrics) – It is top-down approach for collecting the measures on the basis of goals and relative questions.

**M2P** (Meta-Measurement Project) and **MPSP** (Measurement Program Survey Package) – the frameworks designed to assess the structure and effectiveness of measurement programs.

**GQIM** (Goal Question Indicator Measure) – It is an extension in the GQM. It includes the indicators and information needs to track the progress towards achievement of measurement goals.

**OMSD** (Optimum Measures Set Decision) – A model used for optimization of measures and prioritization of the measurement goals.

**M-CMM** (Measurement Capability Maturity Model®) – This model considers measurement as a way of improving the software process quality.

**GAM** (Goal Argument Model) – In this approach the goals are identified as claims and then the data and information that can help in proving the claims are identified.

**QIP** (Quality Improvement Paradigm) - The purpose of QIP is to use the GQM approach in a measurement program at different levels of organization.

**AMI** (Assess, Analyze, Metricate, Improvement) – It utilizes the benefits of the GQM and Software Engineering Institute (SEI) is used in combination with business goals in order to define the activities and measures.

**MIS-PyME** – This framework adopts GQM and GQIM in order to fit the needs of the software measurement program for SME (Small medium Enterprises).

**MIM** (Measurement Information Model) – The purpose of MIM is to help managers in specification of the necessary information for the planning, implementation and evaluation of the measurement program.
PRIMER (Practical Process Improvement for Embedded Real Time Software) – It is a practical approach for systematic selection, integration and use of best practices in the development of embedded software.
2 Systematic Review

According to [14], the purpose of systematic review is to provide more structured way to make an assessment, identification and interpretation of research which is relevant to the specific research question.

It has three phases namely ‘planning the review’, ‘conducting the review’ and ‘reporting the review’. In the planning phase, it is defined that how literature review have been conducted in a systematic manner and a review protocol is developed which acts as a search guide during the systematic literature review. In the second step, systematic literature review is conducted which involves primary studies, quality assessment, data extraction and data synthesis. In the last step, literature review is reported.

Systematic review is an iterative process instead of sequential, because it involves a number of iteration [14]. Example would be inclusion and exclusion criteria, when actual review is conducted several primary studies are included and excluded.

In the following sub-sections, we discuss how we conducted the systematic review.

2.1 Planning the Review

2.1.1 The Purpose of Systematic Review

The rational of systematic review is to identify the effects of goal definition on the success of measurement programs. In this survey, our aim is to identify different ways of goals definition in software organizations.

The GQM and other models such as GAM, GQIM, MIM, MPSP, M2P and Exploratory and Confirmatory Iterative Framework serve as a standard way for defining goals in measurement programs. GQM has been modified according to different context of measurement programs. Our study analyzes the effect of structured goal definition and prioritization on the success of measurement programs.

2.1.2 Review Protocol Development

Review protocol is used to minimize the biasness of researcher(s) [14]. Review protocols consist of methods which help to select primary studies.

Table 3.1.2.1: Document Development Team

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
<th>Role</th>
</tr>
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<tbody>
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<td>Lead Author</td>
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<tr>
<td>Muhammad Ilyas</td>
<td>BTH, Sweden</td>
<td>Second Author</td>
</tr>
<tr>
<td>Dr. Cigdem Gencel</td>
<td>BTH, Sweden</td>
<td>Internal Reviewer/Supervisor</td>
</tr>
<tr>
<td>Faculty Reviewer</td>
<td>BTH, Sweden</td>
<td>External Reviewer</td>
</tr>
</tbody>
</table>
Background

Review protocol consists of inclusion/exclusion criteria, search keywords, databases to be searched, quality assessment checklist, data synthesis, and data extraction form and research questions. Review Protocol developed to identify the current state of the art in measurement programs and goal definition from 01 Jan, 1997 to 01 Mar, 2009. The information and material accessed from the primary study will serve as an input in the development of framework for structured goal prioritization and definition.

Research Questions

Following are the research questions that will be answered during the systematic review:

1. A) How do Organizations use software measurement programs?
   B) What are the success factors in software measurement program?

2. What are the models, frameworks, tools and standards developed for measurement programs?

The questions related to goal prioritization, structured goals and question definition are focused in the following section. The other two questions i.e. Q3 and Q4 which are related to goals prioritization, structured goals and questions definition are answered on the basis of analysis of systematic review.

Searching Strategy

The search process will be done by searching different keywords or terms during the systematic review. These keywords will be searched by using different libraries and databases.

a) Keywords

1. Measurement Programs
2. GQM
3. Structured Goal
4. Goal Definition
5. Role of GQM in Measurement Program
6. 1 AND Challenges
7. 1 AND Success Stories
8. 1 and Software Industry
9. 1 OR Process Improvement
10. 2 AND Process Improvement
11. 2 AND Good Practices
12. Impact of GQM in Industry
13. 4 AND Prioritization
14. Success Factors
15. 1 AND Success Factors
16. 8 AND 15
17. What Measurement Program
18. Why Measurement Program

b) **Resources to be Searched**

Following web resources will be used during the systematic review.

1. Available text books and eBooks
2. Internet
   - IEEExplore
   - ACM Digital library:
     - Google scholar (scholar.google.com)
     - Citeseer library (citeseer.ist.psu.edu)
     - Inspect (www.iee.org/Publish/INSPEC/)
     - Science Direct (www.sciencedirect.com)
3. Journals
   - Company Journals
   - Empirical Software Engineering
   - Information and Software Technology
   - Software Process Improvement and Practice
4. Digital Libraries
   - ACM
   - IEEExplore
   - Springer
### Table 3.1.2.4: List of Selected Conferences and Journals

<table>
<thead>
<tr>
<th>Journals</th>
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<tbody>
<tr>
<td>ACM Transactions on Software Engineering Methodology (TOSEM)</td>
</tr>
<tr>
<td>IEEE Transactions on Software Engineering (TSE)</td>
</tr>
<tr>
<td>IEEE Software</td>
</tr>
<tr>
<td>Springer Software Measurement Journals</td>
</tr>
<tr>
<td>Springer Annals</td>
</tr>
</tbody>
</table>

#### Conference Proceedings

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<tr>
<th>Conference Proceedings</th>
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<tbody>
<tr>
<td>IEEE International Software Metrics Symposium</td>
</tr>
<tr>
<td>IEEE International Conference on Software Engineering</td>
</tr>
<tr>
<td>ACM International Conference on Software Engineering</td>
</tr>
<tr>
<td>IEEE Euromicro Conference on Software Engineering and Advance Application (SEAA)</td>
</tr>
<tr>
<td>IEEE Euromicro Conference on Software Maintenance and Reengineering</td>
</tr>
<tr>
<td>Digital Avionics Systems Conference</td>
</tr>
<tr>
<td>Empirical Software Engineering and measurement (ESEM)</td>
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<tr>
<td>International Workshop on Software Measurement (IWSM)</td>
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<tr>
<td>International Conference on Software Process and Product Measurement (Mensura)</td>
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<tr>
<td>EurSPI (European Software Process Improvement) Conference</td>
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<tr>
<td>Profes (Product and Process Improvement Conference)</td>
</tr>
<tr>
<td>European Software Process Improvement Conference (EurSPI)</td>
</tr>
</tbody>
</table>

These are preceding conferences which are considered during systematic literature review. Some of them are skipped because authors couldn’t find relevant material from them. Following table shows the considered preceding conferences.

#### Selected Conference Proceedings

<table>
<thead>
<tr>
<th>Selected Conference Proceedings</th>
</tr>
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<tbody>
<tr>
<td>IEEE International Software Metrics Symposium</td>
</tr>
<tr>
<td>IEEE International Conference on Software Engineering</td>
</tr>
<tr>
<td>ACM International Conference on Software Engineering</td>
</tr>
<tr>
<td>IEEE Euromicro Conference on Software Maintenance and Reengineering.</td>
</tr>
</tbody>
</table>
Some of the conferences excluded because author(s) of this thesis couldn’t find relevant material related to their research from these conferences. In this research, our main focus is to structured goal and question definition and goal prioritization. These conferences do not fulfill our requirement so we exclude them after study.

<table>
<thead>
<tr>
<th>Excluded Conference Proceedings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profes (Product and Process Improvement Conference)</td>
</tr>
<tr>
<td>Empirical Software Engineering and measurement (ESEM)</td>
</tr>
<tr>
<td>International Workshop on Software Measurement (IWSM)</td>
</tr>
<tr>
<td>IEEE Euromicro Conference on Software Engineering and Advance Application (SEAA)</td>
</tr>
<tr>
<td>European Software Process Improvement Conference (EurSPI)</td>
</tr>
</tbody>
</table>

Study Selection Criteria

The selection of research articles is based on title, abstract, and conclusion. Following is the inclusion and exclusion criteria:

a) Inclusion Criteria

The articles/journals on ‘software measurement programs’ published 01 Jan, 1997 to 01 March, 2009 are included. The following inclusion criteria were used in order to include in systematic review.

- The articles/papers that talk about measurement programs in software industry.
- The articles/papers that talk regarding Goal Question Metrics.
- Empirical studies regarding measurement Programs.
- General papers that directly related to the topic as well as research question.
- The articles should be accessible in full text.

b) Exclusion Criteria

- The study containing the irrelevant information to the research questions.
- The study in any language except English will be excluded.
- The study with the irrelevant material will be excluded.
Quality Assessment Checklist

It is essential to evaluate the quality of primary studies during inclusion/exclusion criteria [14]. The purpose of the quality assessment in this research is to weight the importance of individual studies during data synthesis.

Table 2.1.2.6: Quality Assessment Checklist

<table>
<thead>
<tr>
<th>Type</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bias</td>
<td>To check the completeness of the results i.e. true results are presented, in addition pros and cons of an object that was under study.</td>
</tr>
<tr>
<td>Internal Validity</td>
<td>To determine the research and experimental design i.e. to analyze the chances of errors in the results.</td>
</tr>
<tr>
<td>External Validity</td>
<td>To determine the use of results in practice.</td>
</tr>
<tr>
<td>Generalization</td>
<td>Do the results are generalizable?</td>
</tr>
<tr>
<td>Completeness</td>
<td>Does the specific study provide pros as well as cons of understudied object?</td>
</tr>
</tbody>
</table>

Data Extraction Strategy

We extracted the facts and figures which were presented in different dimensions of goal definitions in the form of models and frameworks and tools.

a) Common Information about Research Study:
   1. Article Title
   2. Author(s) Name(s)
   4. Search Keywords to Access Research Articles
   5. Source of Research Articles
   6. Date of Publication

b) Explicit Information about Research Study:
   1. Study Context
      - Empirical
      - Academia
   2. Research Methodology
      - Action Research
      - Experiment
      - Case Study
      - Survey
   3. Subjects
      - Professionals
      - Sampling Criteria
   4. Goal Definition
      - Model(s)/Framework(s) used for Goal Definition
      - Standards for Goal Definition
      - Tool(s) for Goal Definition
      - Techniques for Goal Definition
      - Problems in Goal Definition
      - Solution related to Goal Definition
      - Evaluation of Goal Definition Techniques
• Comparison of Goal Definition Techniques

5. Question Definition
  • Model(s)/Framework(s) used for Question Definition
  • Standards for Question Definition
  • Tool(s) for Question Definition
  • Techniques for Question Definition
  • Problems in Question Definition
  • Solution related to Question Definition
  • Evaluation of Question Definition Techniques
  • Comparison of Question Definition Techniques

6. Validity Criteria
  • Internal Validity
  • External Validity
  • Conclusion Validity
  • Construct Validity

Synthesis of the Extracted Data
The purpose of data synthesis is to propose a conclusion on the basis of collected data analysis. The studies in systematic review are heterogeneous because of different methodology and outcomes. Qualitative synthesis is performed because of heterogeneous nature of data. The outcomes of the systematic review will be according to research questions as stated in the review protocol. Data extraction forms will be used in order to get information from key studies.

2.1.3 Evaluation of the Review Protocol
The evaluation of review protocol is done according to the guidelines given by Kitchenhamm [14]. The review protocol was reviewed by our thesis supervisor in order to determine the expected outcome.

2.2 Conducting the Review
2.2.1 Identification of Research
The purpose of a systematic review is to identify various aspects related to the research questions by using a particular research strategy. The search strategy is defined in the review protocol.
In order to define search keywords, research questions are divided into different categories like study background, models, outcomes, and population. The synonyms of the keywords are used in order to perform research. Boolean AND to join and OR are used to include synonyms in order to conduct search. The use of population concept in the review protocol is to identify:

1. A particular area of software engineering.
2. An application of the particular research area.
3. The stakeholders of the particular research area.
4. Identify all available tools, techniques and frameworks/models.

The publication bias is one of the major issues of systematic review. The publication bias is related to present the discussion according to personal opinion. The manual searching, online blogs and discussion forums were also analyzed in order to avoid the biased results. The Endnote was used to maintain the list of references of selected articles and journals that are obtained by systematic review. The main purpose of using Endnote was to eliminate the possibility of double insertion of specific articles.
2.2.2 Selection of Primary Studies

There are two steps in the selection process of primary studies. In the first step, title, abstract, and conclusion of the research papers are analyzed for selection/rejection. The selection process in the first step was done on the papers obtained after applying different combinations of key-words in the identified digital libraries. The papers selected in the first step were further filtered against the inclusion/exclusion criteria defined in the review protocol.

<table>
<thead>
<tr>
<th>No.</th>
<th>Ref#</th>
<th>Articles</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>[28]</td>
<td>Practical experiences of tool support in a GQM-based measurement program, 1997.</td>
</tr>
<tr>
<td>8</td>
<td>[38]</td>
<td>Measurements should generate value, rather than data [software metrics], 1999.</td>
</tr>
<tr>
<td>14</td>
<td>[41]</td>
<td>Integrating goal-oriented measurement in industrial software engineering: industrial experiences with and additions to the Goal/Question/Metric method (GQM), 2001.</td>
</tr>
<tr>
<td>28</td>
<td>[46]</td>
<td>To decision on selecting the minimal required set of measures from a number of possible measures</td>
</tr>
</tbody>
</table>
In the first step more than 1169 articles were scanned and 69 articles were selected. The final set of articles after the second step consists of 27 articles. The titles of selected articles after the review are provided in the following Table 3.2.2.2. The references of the selected papers were defined in the Endnote library. The manual search was done to ensure that all the conference proceedings have been covered and no key article is missed. The statistical representation of the selected articles is given in Table 3.2.2.2. The titles of the selected articles are given in Table 3.2.2.1.

### Table 3.2.2.2: Selected Articles from Conferences/Journals

<table>
<thead>
<tr>
<th>S. No</th>
<th>Journal</th>
<th>Total Articles</th>
<th>Articles on M.P</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ACM Transactions on Software Engineering Methodology (TOSEM)</td>
<td>62</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>IEEE Transactions on Software Engineering (TSE)</td>
<td>61</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>IEEE Software</td>
<td>65</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>Springer Software Measurement Journals</td>
<td>788</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Springer Annals</td>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>IEEE International Software Metrics Symposium</td>
<td>115</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>IEEE International Conference on Software Engineering</td>
<td>45</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>ACM International Conference on Software Engineering</td>
<td>21</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>IEEE Euro-micro Conference on Software Maintenance and Reengineering</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Digital Avionics Systems Conference</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>International Conference on Software Process and Product Measurement (Mensura)</td>
<td>79</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>Empirical Software Engineering and measurement (ESEM)</td>
<td>195</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>IEEE Euromicro Conference on Software Engineering and Advance Application (SEAA)</td>
<td>132</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>1580</strong></td>
<td><strong>28</strong></td>
</tr>
</tbody>
</table>

### 2.2.3 Study Quality Assessment

Study quality assessment is done in order to perform inclusion/exclusion criteria. We used checklist to facilitate study quality assessment by dividing internal validity, external validity, biasness and completeness as it defined in section 3.1.2.6.
2.2.4 Data Extraction and Monitoring
The main purpose of this section is to develop data extraction forms in order to record the information which is obtained from the primary studies. The authors performed data extraction with the review protocol in order to condense the chances for bias. Therefore these forms should be piloted during the review protocol is defined. In this phase, both authors work parallel as it conform that all main information is extracted from the research articles.

2.2.5 Data Synthesis
It involves extracting and summarizing the results of the selected primary studies [14]. The data which is extracted from primary studies should be helpful to answer the research questions. Data synthesis can be expressive synthesis, quantitative or qualitative synthesis [14]. In descriptive synthesis, information should be in tabular form and is consistent with research questions which are defined in review protocol [14]. The qualitative synthesis involves the studies that results after the analysis of theoretical grounds, language results and conclusions. According to [14], there are three approaches available for qualitative data synthesis.

In this study we followed line of argument synthesis because firstly, we analyzed the studies individually and then in the later step we analyze the studies as a whole.

1. Reciprocal translation
The reciprocal translation is useful when researches are trying to have additional information about different aspects of object under study.

2. Refutational synthesis
The refutational synthesis is useful when researchers are providing the implicit or explicit refutations of each other.

3. Line of argument synthesis
The line of argument synthesis is useful when researchers are trying to conclude or infer about a topic by analyzing a topic as a whole. It has two steps. In the first step the relevant studies are analyzed individually and in the second step the studies are analyzed as a whole.

2.2.6 Reporting the review
The procedure and style of this systematic review is qualitative. There was small amount of relevant information about the structured goals and prioritization in software measurement programs. Therefore we analyzed the aspects that are relevant to this topic and made a systematic review about them to identify the improvement areas.

2.3 Systematic Literature Review

2.3.1 Analysis
In order to answer RQ1, we first categorized the research articles as in Table 4.1.1.2.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Ref. No.</th>
<th>Study context</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>{3, 10, 17, 26}</td>
<td>Industrial + Model Validation</td>
</tr>
<tr>
<td>2.</td>
<td>{36, 40, 42, 44}</td>
<td>Industrial (Survey)</td>
</tr>
<tr>
<td>3.</td>
<td>{16, 37, 41}</td>
<td>Qualitative Research</td>
</tr>
<tr>
<td>4.</td>
<td>{15, 19, 38}</td>
<td>Industrial Case Study</td>
</tr>
</tbody>
</table>

In the following paragraphs, details of analysis of literature review to answer RQ1-a, and RQ1-b are discussed.
2.3.1.1RQ-1a: How do Organizations use software measurement programs?

Table 2.2.7 shows the primary studies along with authors of those studies and contribution levels of studies. In the right column, contribution of studies about *usage of software measurement program* is shown by using scale i.e. partial, full.

Table 2.3.1.1: Coverage of Articles Regarding Usage of Measurement Programs

<table>
<thead>
<tr>
<th>Ref. No.</th>
<th>Article name</th>
<th>Author</th>
<th>How Use SMP?</th>
</tr>
</thead>
<tbody>
<tr>
<td>[38]</td>
<td>Measurements should generate value, rather than data [software metrics], 1999.</td>
<td>Frank Niessink, and Hans Van Vliet</td>
<td>Full</td>
</tr>
<tr>
<td>[41]</td>
<td>Integrating goal-oriented measurement in industrial software engineering: industrial experiences with and additions to the Goal/Question/Metric method (GQM), 2001.</td>
<td>Rini van Solingenen, Egon Berghout</td>
<td>Full</td>
</tr>
</tbody>
</table>

**Analysis**

Implementing a measurement program is a well defined structured approach in order to gather and process the data continuously throughout the software development lifecycle. The main purpose of software measures is to extract good from the raw data [17, 40] and measurement programs are used to apply these software measures in management and technical aspects [3]. Software measures are used to classify the best practices i.e. Software Process Improvement, estimating and planning projects effectively, manage budget effectively, and it also helps comparison of current practices and tools. Software measurement programs provide a source for industry comparison and facilitate effective communication between developer and customer [41]. Measurement programs start with definition of goals and their respective questions which leads to formation of metrics. At the start, an organization needs to set proper objectives for what they are going to do and then start measuring.

An organization sets goals before starting implementation and these goals intend to satisfy the organizational business objectives. The mapping of these goals with appropriate measures requires experienced resources in the field of software measurements. These goals should be prioritized so that relevant and important measures are selected to be collected and
analyzed accordingly. There are some reasons which highlight the importance of measurement programs in industry. These are discussed in the following sub-sections.

**Monitor and Control**
According to [10], the implementation of a successful measurement program is very difficult and its maintenance is more difficult. Software measurement programs collect data and convert it into information. Software process measurement has critically importance [10] in order to monitor and control the development process and current activities of the project. The main purpose of measurement process is to monitor and control different factors that can affect the measurement programs i.e. Cost, Time, Quality, and overall performance of an organization.

**Decision Making**
Measurement programs help organizations in order make important decision and improve the decision making [37]. These decisions are usually based on statistical analyses. Results from each project are stored in database and they will be useful in decision making for the next projects in order to achieve continuous software process improvement [10].

**Software Process Improvement**
Measurement programs offer a well-structured approach to software implementation and software process improvement (SPI) [10], as it gives more benefits to management over those who still adopt traditional approaches. If an organization plans to improve their processes then measurement data helps by identifying which phases need to improve. The measurement data saves in database for reusability.

**Performance Improvement**
In a measurement program, relationship among the products, process and resource variables are declared. The purpose of defining this relationship is to identify how the performance of measurement program is affected? This is an iterative process in which assumptions are made, filtered or rejected [38].

**Organizational Health**
The measurement programs can be used to evaluate the processes of an organization against some assessment criteria such as defined by CMM or CMMI. Here, the set of recommendations are made in order to improve the processes [38].

2.3.1.2 RQ-1b: What are the success factors in software measurement programs?
Table 2.3.1.2 shows the findings related to success factors in software measurement program. The contribution of primary studies is shown by using scale of full, partial and none.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Title</th>
<th>Authors</th>
<th>Scale</th>
</tr>
</thead>
</table>
Analysis

In [18], [37], [38], [41] and [44] measurement programs success factors are discussed. Measurement programs play significant role in the success of a project. In order to start an efficient measurement program [16], it is important to understand precisely the rationale of using measurement and our objective regarding measurement i.e. what do we want to accomplish? Measurement programs are implemented in a structured way which is more efficient and effective [37]. In order to start measurement program in an organization, [18] have quoted 10 steps that will be useful in order to start measurement program:

- **Define the objectives for the software metrics program** – Every organization should specify their objective i.e. why and what they want to measure? Defining objectives is very crucial for success of any measurement program.
- **Assign responsibility** – An organization should hire competent and expert resources for measurement.
- **Do research** – A research should be done on different perspectives of applying it. Cost-benefit analysis should be done in order to avoid any risk.
- **Define initial metrics to collect** – After research initial set of metrics are collected and start data gathering by using set of metrics.
- **Sell the initial collection of these metrics** – Once the data has collected, sell the collected measures data, determine its benefits and give suggestions to higher management to use it properly.
- **Get tools for automatic data collection and analysis** – automatic data collection tools are needed for better time utilization. These tools are collect and analyzed data and save resource time.
- **Establish training in software metrics** – when measurement program is experienced by organization then training session is needed to give knowledge about measurement program.
- **Publicize success stories** – It is important to spread the advantages of measurement in order to enlarge measurement program.
- **Create a metrics database** – The results of a measurement program saved to measurement database and these results can be use as a baseline for upcoming projects.
- **Establish a way for improving the process in an orderly way** – The results and data from measurement program are used to help and improve the measurement process in a systematic manner.

These steps are generic in nature and different organization can adopt and modify according to their goals and objectives. Example of Nokia [19] is given below:

- **Metrics Definition** – Metrics definition is defining a metrics that follows the same structure as Software Process Improvement does.
Data Collection – Data collection is more mature process as it involves a lot of management. ‘Nokiaway’ metrics program uses four different tools for data storage for collecting metrics i.e. Resource and Project, Fault, Test Case and Review and Inspection.

Metrics Analysis – Metrics analysis plays a vital role in metrics definition. It ensures that metric’s results have been analyzed with some instruction.

Metrics Reporting – Metrics results and analysis are usually view by everyone. These results published on web or view from database.

According to [17, 40], success of measurement programs depends on two stage approach. In the first stage, organization uses output from the measurement program for decision making. In the second stage, consistent use of these output for decision making increase the performance of the organization. On the basis of aforementioned approach, success factors are divided into two categories; Technical Factors and Organizational Factors.

Technical Factors

- **Metrics Collected** – Industrial experiences show that to use and collect the right measurements is very important because it help out in decision making.
- **Training** – Training plays a vital role in measurement program, because it requires expertise. So trained resources will give potential benefits to the organization.
- **Metrics Analysis** – is the key success factors by which you analyze and compare the results with current practices.
- **Data Collection Procedures** – data collection procedures are important because these procedures increase the result accuracy and developer’s efficiency.
- **Quality of Metrics** – Quality metrics should be informative and their outputs interpret to the organizational context.
- **Automated Tools** – Use of automated tools reduce the data collection time and make the analysis more accurate and precise.
- **Communication and Feedback** – These are the most important key factors and important to decision makers. Metrics communication and timely feedback make measurement program more efficient.

Organizational Factors

- **Stakeholders Involvement in setting Metrics Goals** – It is important that internal and external stakeholders should participate in order to decide metrics goals.
- **Resource Sufficiency** – It is necessary for the organization to have sufficient resources, otherwise measurement programs fail badly.
- **Management Support** – Manage support is important in order to institutionalize the measurement programs in an organization. It also helps management in decision making.
- **Maturity Level** – Maturity Level shows the discipline in organization’s processes. More mature organization gets more benefits than the less mature organization.

2.3.2 RQ-2: What are the models, frameworks, tools and standards developed for measurement programs?

There are various models/frameworks, tools and techniques proposed that can be used in a measurement program. There are various purposes of the measurement program as also
described in the previous section. One of the primary purposes of measurement program is to improve the quality of the organizations. We have done the systematic review to identify and analyze different types of measurement programs in industrial and non-industrial context. The models/frameworks, tools and standards are described according to two views:

1. How the goals are defined in the model/framework, tools and standards?
2. How the model/framework, tool and standards support the improvement in overall quality of the organization?

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Reference</th>
<th>Model/framework</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>{5, 22, 11, 33, 41, 43}</td>
<td>GQM</td>
</tr>
<tr>
<td>2.</td>
<td>{23}</td>
<td>GAM</td>
</tr>
<tr>
<td>3.</td>
<td>{27}</td>
<td>GQIM</td>
</tr>
<tr>
<td>4.</td>
<td>{15}</td>
<td>M-CMM</td>
</tr>
<tr>
<td>5.</td>
<td>{24}</td>
<td>AMI</td>
</tr>
<tr>
<td>6.</td>
<td>{10, 25}</td>
<td>MIS-PyME</td>
</tr>
<tr>
<td>7.</td>
<td>{26}</td>
<td>MPSP</td>
</tr>
<tr>
<td>8.</td>
<td>{3}</td>
<td>M2P</td>
</tr>
<tr>
<td>9.</td>
<td>{12}</td>
<td>MIM</td>
</tr>
<tr>
<td>10.</td>
<td>{6}</td>
<td>Exploratory and Confirmatory Iterations Framework.</td>
</tr>
</tbody>
</table>

**Measurement Tools**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Reference</th>
<th>Measurement Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.</td>
<td>{28, 29}</td>
<td>PRIMER</td>
</tr>
<tr>
<td>12.</td>
<td>{28}</td>
<td>Metri Flame</td>
</tr>
<tr>
<td>13.</td>
<td>{39}</td>
<td>GQM-Plan Tool</td>
</tr>
</tbody>
</table>

**Measurement Standards**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Reference</th>
<th>Measurement Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.</td>
<td>{12}</td>
<td>ISO/IEC 15939</td>
</tr>
<tr>
<td>15.</td>
<td>{29, 30}</td>
<td>ISO/IEC 9126</td>
</tr>
<tr>
<td>16.</td>
<td>{31, 32}</td>
<td>ISO/IEC 15504 SPICE</td>
</tr>
<tr>
<td>17.</td>
<td>{34, 20}</td>
<td>CMM</td>
</tr>
<tr>
<td>18.</td>
<td>{21}</td>
<td>CMMI</td>
</tr>
</tbody>
</table>

### 2.3.2.1 Models

This section comprises the models, frameworks, standards and tools which use improve measurement program in software industry.

**CMM (Capability Maturity Model)**

The aim of CMM is to mature the processes of an organization to improve the product quality. The process of maturing the processes in an organization consists of five levels. Each level contains the detailed information in the form of Key Process Areas (KPAs), goals, common and key practices to ensure a specific maturity level [34]. Each KPA has a set of goals as the goals are according to the purpose and scope of the process. The Key processes can be defined in terms of activities, resources, deliverables and cost. The common features are the practices that are required to implement the process to achieve the goals. The key practices are those activities that are vital and effect directly on the level of achievement of goals. The level of achievement of goals at a maturity level helps in identifying the capability of the organization at that maturity level [20].

**CMMI (Capability Maturity Model integrated)**

The CMM was developed initially to mature the processes for software development. It proved a success and it was later on designed for people, system engineering, and software acquisition. It was difficult to implement and manage the CMM across the organization due to its complexity and the need for a more integrated approach.
to conflicts and lack of integration between the different modules [21]. So CMMI was developed to resolve the above mentioned problems.

The goals of CMMI include [21]

- Definition and prioritization of process improvement goals
- Guidelines for the process quality
- Integration of functions and process in different areas of organization

CMMI not only utilizes the best practices for the product and services but it also provides the recommendation for the improvements in the available models. The best practices of CMMI help organization in

- Defining relationship among business goals, management and engineering activities
- Making traceability of the business goals possible within the software development life cycle (SDLC).
- Ensuring control over the important activities in an organization.

The CMMI can be adopted in two ways i.e. staged and continuous. The stage adoption of CMMI is better for the organizations that already have CMM processes and wants to shift towards CMMI. The continuous CMMI is useful to make continuous improvement plans that are more aligned with the business goals.

**M-CMM**

Measurement programs run parallel to the software development and maintenance. The purpose of measurement programs is not only to assess and control but also improve the process quality in software development. There are different approaches like M-CMM, BOOTSTRAP for software process improvement. These approaches consider measurement as a way of improving the software quality. In M-CMM, the measurements must be a part of all key process areas to control the progress of software development process. The measurement in M-CMM is intentionally done level 4 with the help of Quantitative process management. The purpose of M-CMM is to improve the quality of the software process but not specifically with the help of implementing and improving the measurement program [15]. In [15], Measurement capability maturity model (M-CMM) is proposed. The main goal of M-CMM is to estimate and predict the capability of the organization in terms of software development process. The M-CMM focuses on helping the organizations in improving the measurement capability. The M-CMM is described in Table 2.3.2.1.1

<table>
<thead>
<tr>
<th>Maturity level</th>
<th>Description</th>
<th>Key Process Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>No measurement processes, measures are collected at individual level.</td>
<td>No KPA(s)</td>
</tr>
<tr>
<td>Repeatable</td>
<td>Basic measurement process for measurement goals specifies measures, measurement protocols, collect and analyze measures and provide feedback to software engineers and management.</td>
<td>Measurement Design, Measure Collection, Measure Analysis, Measurement Feedback</td>
</tr>
<tr>
<td>Defined</td>
<td>Documentation, standardization and integration of measurement process are done with the software process.</td>
<td>Organization Measurement Focus, Organization Measurement Design, Organization Measurement Database, Training</td>
</tr>
</tbody>
</table>
Managed
<table>
<thead>
<tr>
<th>Program.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Managed</td>
</tr>
<tr>
<td>Quantification of software measurement process is done. Measurement process is efficient and cost of measurement in known.</td>
</tr>
<tr>
<td>Measurement Cost Management, Technology Selection</td>
</tr>
</tbody>
</table>

Optimizing
<table>
<thead>
<tr>
<th>Program.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimizing</td>
</tr>
<tr>
<td>Measurement process is monitored and improvements are made. Flexible measurement goals are set with respect to the organization and environment.</td>
</tr>
<tr>
<td>Measurement Management</td>
</tr>
</tbody>
</table>

Following figure 2.3.2.1.1 shows the relationship between the M-CMM and Measurement objects with respect to SW-CMM [15].

ISO/SPICE (International Standard Organization/ international Electro-technical Commission) 15504

The purpose of ISO/IEC 15504 standard is process assessment so that an organization can improve their processes in order to achieve their business goals. The assessment and audits are done to identify the level of maturity of their processes. The results of the assessment are analyzed to see improvement areas to achieve the business goals in an effective and efficient way. This standard is a practical and cost effective approach for SMEs. The inputs from the process are compared with the process assessment standard of SPICE. The analysis of the comparison provides an insight to the organization to improve the processes. There are nine process attributes are defined in this process and the rating scale is used in order to know level of achievement [31, 32]. The attributes of the process are definition, deployment, measurement, control, innovation, performance, performance management, work product management, and optimization. The maturity of the processes is divided into four levels i.e. not achieved, partially achieved, largely achieved and fully achieved.

Table 2.3.2.1.2: Description of levels in ISO/IEC 15504

<table>
<thead>
<tr>
<th>Maturity Levels</th>
<th>Name</th>
<th>Process Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Optimizing process</td>
<td>Process Performance</td>
</tr>
<tr>
<td>2</td>
<td>Predictable process</td>
<td>Performance Management, Work Product Management</td>
</tr>
</tbody>
</table>
Established process | Process Definition, Process Deployment
---|---
Managed process | Process Measurement, Process Control
Performed process | Process Innovation, Process Optimization

**GQM (Goal Question Metrics)**

The bottom-up approach in a measurement programs has problems because the data is collected and evaluated without a plan. The GQM is a goal oriented approach developed by Basili and Weiss [5]. There are various changes done in this framework i.e. GAM, GQIM. The purpose of these changes was to overcome the deficiencies in this approach. The GQM is a top-down approach in which specific goals are defined at conceptual level, then questions are asked that can answer the degree of achievement of goals at the operational level and at the last level i.e. quantitative level, metrics are defined to provide the quantitative and qualitative answers of the questions. The relationship between the questions and metrics can be one-to-one, one-to-many or many-to-many. The first step of GQM is goal definition which helps in identifying the scope of raw data and information to be collected. The identification of scope helps in minimizing the cost and effort for data collection as only needed data is collected [22]. According to [22], there are four phases of application of GQM i.e. planning, definition, data collection, interpretation.

![GQM framework](image)

The GQM goals are identified in the definition phase. The interviews can be conducted with stakeholders that are involved in the process or product under study. The questions are asked for each goal and there should be a hypothesis defined for the answer of each question [22]. The measurement is done in the data collection phase. The measurement can be done with the help of automated data collection tools or manually. The measurement tools usually consist of spreadsheets, statistical tools, and database application and presentation tools to show the results in different ways [11], [33]. The results are evaluated against the goals to monitor, control and improve the current processes of software development and measurement program.
The goals must be specified and documented in a structured way. In [22], a template is provided in order to specify the goals and questions in a structured way.

“Improve (=purpose) the reliability (=issue) of product X (=object) from the viewpoint of the user (=perspective) within organization Y (=context).”

Similarly if the questions are also defined in a structured way then it can help in avoiding the ambiguities, misconception and conflicts. For example a question could be,

“What is the Mean Time to Failure for function y() in class xyz in the version 1.0 of a product A”? 

In [41], the cost benefit analysis, success factors, industrial experience, stakeholder issues relevant to GQM and measurement program are discussed in detail. According to [43], measurement goals are derived from the business goals of the organization, available data and information about the processes and resources. In order to define the measurement goals there is need of a framework i.e. GQM with the guidelines to structure them in an appropriate way.

GAM (Goal Argument Metrics)

According to [23], GAM provides the Argument structure for the derivation of metrics from measurement goals. The main problems in measurement programs which affect the overall quality of the organization are following:

- Problems in identifying the scope of the raw data and information to be collected.
- Problems in selecting the metrics that fulfill the purpose and do not require extra cost.

Aforementioned problems require an effective method of derivation of metrics and efficiently describing the scope and amount of data required [23].
In this approach the goals are identified as claims and then the data and information that can help in proving the claims are identified. In the start of this process, it is supposed that that the measurement goals have been achieved. The argument(s) is given to support the claim. The claims can be divided into sub-claims in an iterative way, until the claims can be supported by a metric(s). These claims are used to identify and enlist the metrics. In the end, metrics are decomposed into direct metrics, which defines raw data scope. Figure 2.3.2.1.5 shows the comparison of GQM and GAM approaches [23].

**GQIM (Goal Question Indicator Measure)**

The GQIM [12] has three rules/guidelines:

- Business goals are used to specify the measurement goals.
- The improvement in mental model (based on experience) provides the focus on the issues and understanding of context.
- The purpose of GQIM is translation of business goals into the structured measurement goals.

The application of the GQIM is sequential approach. It is consist of following steps [12].
- Identification of business goals of project/process/organization.
- Identification of field/concept/value to find or learn.
- Identification of sub-goals.
- Identification of entities and their attributes relevant to the sub-goals.
- Formalization (making structure) of the measurement goals.
- Identification of the quantifiable questions and indicators of level of achievement of goals.
- Identification of the data elements.
- Provide definition of the required measures.
- Identification of the activities and tasks that will be performed to collect the measures.
- Make a plan to for implementation of the measurement plan.

**QIP (Quality Improvement Paradigm)**

The purpose of QIP is to use the GQM approach in a measurement program. The improvement activities in the QIP can be used at different levels i.e. Project, organizational levels. Every step in the QIP has specific measurement activities [42]. The following figure 2.3.2.1.6 presents the six steps of QIP and relevant activities.

![Figure 2.3.2.1.6: Quality Improvement Paradigm [42]](image)

**AMI (Assess Analyze Metricate Improve)**

The AMI is the detailed method that an organization can use to initiate the improvement process. It utilizes the benefits of the GQM and Software Engineering Institute (SEI) is used in combination with business goals in order to define the activities and measures [24].

**AMI Application**

An organization must perform the following key task after the identification of the problem:

- Make the business goals according to goal definition in CMM.
- Derive the improvement goals.
- Make a strategy to attain the above mentioned goals.
- Identify and define the metrics that will be used throughout the process to monitor and control the progress towards those goals.

In [24], it is stated on the basis of industrial experience that analysis and benchmarking are two approaches that can be used for the process improvement. The SEI CMM is a benchmarking approach in the software process. In order to get the effective results both the above mentioned approaches should be used in combination and AMI supports this combination. The AMI method has four steps to improve the quality of software measurement program i.e. Assess, Analyze, Metricate, Improve.

**Assess:** Goals for the measurement program are defined after the assessment of the goals and problems of the project.

**Analyze:** A goal tree is defined by decomposing the goals in to sub-goals, question and required metrics. There should be involvement of the stakeholders in this step.

**Metricate:** The measurement plan is implemented, raw data and collected information is converted into the measurement format. The results of measurement are obtained by processing the data and information according to the plan.

**Improve:** The results of measurement program are compared against the measurement goals. This comparison helps in identifying the improvements in the goal definition, planning and implementation of measurement program.

According to [24], when MIM is applied in the industry the combination of measurements and assessment results of CMM proved very useful. It is also learned that simple metrics should be used at the lower level of maturity. It is also noted that if the measurement improvement plans are over ambitious then frustration can be created within the people of the organization. There is need of identifying the appropriate indicators that can help in monitoring the progress towards achievement of goals.

![Assess, Analyze, Metricate Improve – Model [24].](image)

**MIS-PyME framework**

According to [10, 25], mostly the software development companies (77% in Germany, 69 % in Brazil, 92 % in Mexico (2002)) are Small Medium Enterprises (SMEs). So there is need of attention towards software measurement in SMEs. MIS-PyME is step-by-step method for setting measurement programs in the SMEs on the basis of software indicators. This
framework adopts GQM and GQIM in order to fit the needs of the software measurement program for SMEs. This framework is made on the assumptions

- The stakeholders in SMEs including measurement analyst usually do not have much experience in the measurement.
- The culture of measurement, knowledge and procedures are not highly effective. The procedures for data collection, training are not well defined.
- The resources are less as there are approximately less than 50 people.

This framework provides a set of structured goals for measurement process. The measurement goal table proposed in this framework consists of ten process improvement goals and 150 measurement goals. These goals are defined with respect to the maturity level of measurement. Figure 2.3.2.1.8 shows an example of measurement goals of product, process and resources. The indicator template is also defined in this framework that helps the measurement personnel to select the indicators and identify the required measures to fulfill goals [10].

![Figure 2.3.2.1.8: MIS-PyME Framework](image)

There are five maturity level defined in this framework [25].

- **Level 1**: no measurement.
- **Level 2**: measurement is done in order to manage project milestones, project tracking and tracking quality.
- **Level 3**: measurement models are developed at the organizational and project level. The work is managed at the work package level to maintain the quality of the product.
- **Level 4**: The measurement model contains the required number of measures. Product development and quality is monitor and controlled at a broader level.
- **Level 5**: The main focus is process improvement. The measurement process is controlled by identifying and avoiding the problems and keeping the technology needs up to date.

**MPSP (Software Measurement Program Survey Project)**

Software measurement program is an iterative process which can be supported by defining, designing, constructing, implementing, operating and maintaining an information system. This process can help in data collection, analysis and communication of the results for
improvements. There is need of standards, procedures, tools, techniques and resources [26]. The MPSP is based on the above mentioned concept. According to MPSP the results of the measurement program are compared with the success factor values. This approach also helps in identifying the new success factors [26].

**M2P (Acronym for Meta measurement)**

The purpose of this framework is the measurement of measurements i.e. to see the accuracy and effectiveness of the measurement. In this method different models are used in order to assess and improve the quality of software product. This model measures the performance according to different views i.e. user, process, product, value-based, resource, context and social view.

M2P framework gathers data and information to analyze measurement products, implemented processes and quality of results provided in the measurement and analysis process. It helps in management of the measurement process [3].

- M2P defines the set of performance factors to perform the assessment of the measurement.
- A model is developed for assessment according to the structure of the organization.
- Collected data after the observation of the performance of measurement is compared with the best practice.
- The social impact of the measurement is analyses according to ethical, legal and political norms.
- The assessment is analyzed with respect to priorities of the organization in the measurement program.
- A model is designed on the basis of observation and assessment results to improve the performance of the measurement process in an organization.

**Exploratory and Confirmatory Iterative Framework**

In [6], exploratory and confirmatory iterative framework helps in making data collection process more structured and well-defined. By the usage of this framework, one can prevent cost by avoiding the collection of unnecessary data. The exploratory and confirmatory processes are two iterative processes that can run independently but they compliment each other (see Figure 2.3.2.1.9).

In the exploratory phase the assumptions are made about the causes of problem in the measurement program and in the confirmatory phase the metrics and collection criteria is defined. The tasks in the confirmatory phase also helps in identifying the validity of the assumptions. According to [6], exploratory and confirmatory framework can help in defining structured goals for measurement programs.

![Figure 2.3.2.1.9: Exploratory and Confirmatory Iterative Framework](nitropdf.com/professional)
MIM (Measurement Information Model)

The purpose of MIM is to help managers in specification of the necessary information for the planning, implementation and evaluation of the measurement program. The MIM model uses the term measurable concept, i.e. the abstract relationship between the information need and the attribute of an entity [12]. The example of the measurable concepts includes the customer value, quality and risk. The measurable concept can help in developing the structured goals of a software measurement program. The following figure shows the MIM model.

![Figure 2.3.2.1.10: Measurement Information Model [12]](image)

### 2.3.2.2 Measurement Programs Tools

The measurement program improves the overall quality of the organization. Different organizations develop tools on the basis of measurement models which can be used to make the measurement process efficient, accurate and less time consuming in terms of time. Following are the measurement tools that are being used by the organizations and there implementation results are discussed in the research papers.
PRIMER (Practical Process Improvement for Embedded Real Time Software)

As described in [28], GQM is a goal driven methodology starting from the business specific goals and define metrics to answer the level of achievement of goals. The measurement results then can be used for evaluation of the business goals and measurement program. PRIMER (Practical Process Improvement for Embedded Real Time software) is a practical approach for systematic selection, integration and use of best practices in the development of embedded software. It consists of four steps:

- Analysis of current practices
- Definition of goals for improved practices
- Plan for process improvement steps
- Piloting and using in the product development

The first step consists of analysis of both qualitative and quantitative factors. The quantitative analysis is performed by using SPICE, Bootstrap, CMM or Trillium assessment method. The quantitative analysis is performed with the help of following-up actual performed work and analysis framework. Qualitative analysis is the description of the processes, organizational context, application domain, software development and management practices and prioritizes areas of improvement [29].

![Figure 2.3.2.2.1: Practical Process Improvement for Embedded Real Time software](image)

The analysis framework consists of the following:

- Organizational context and application domain
- Software development and management practices
- Process related problems
- Definition of prioritized improvement areas

The new process or sub-process include a model, software development method and tool support for these methods [28].

Metri-Flame

In this approach the data and information about the measures is gathered from various external sources and the results of measurements are used for the evaluation of the goals. The collection of data for the measurement objects can collect from testing tools, project management tools, defect databases, document databases, training data bases. This tool can be used in any software development process to collect data and information for the measurement program [28].
Metri-Flame converts the collected data into its own format in order to calculate the metrics according to their definitions. The results of the measures can then be converted into a format (for example Excel, pie charts etc) to evaluate the results with respect to measurement goals.

Figure 2.3.2.2: Metri-Flame [28].

GQM-PLAN Tool
This tool helps in making measurement plans for quality assessment in an organization. This tool is based on the GQM process of Goal definition, metrication and question derivation. This is achieved by using a database to manipulate the measurement goals, quality perspective and hypothesis development. The variation in the hypothesis and goal achievement is monitored in it [39].

Figure 2.3.2.2.3: Structure of the GQM-PLAN tool [39]

2.3.2.3 Standards
ISO/IEC 15939
The purpose of this standard is to improve the software measurements with the help of identification, definition, selection and application of necessary tasks and activities.
The standard does not recommend any measurement model for the organization. The users can tailor this model according to the context, culture, and structure of software processes in the organization [12]. The documentation of the processes of the standard are not explicitly specified.

There are various concepts and terms used in this standard. Some of important terms in ISO/IEC 15939 with respect to definition of goals are described below:

- **Information need**: insight necessary to manage objectives, goals, and problems.
- **Information product**: one of more indicators and their associated interpretations that address information need.
- **Indicator**: measure that provides an estimate or evaluation of specified attribute derived from a model with respect to defined information needs.
- **Entity**: An object i.e. product, process, or resource.

![Figure 2.3.2.3.1: Workflow of ISO/IEC 15939 [12].](image)

**Establish and sustain the measurement commitment**: In this step requirements for measurement are finalized and resources are assigned.

**Plan the measurement process**: In this step:
- The object (product, process, resource) whose properties are going to be measured is identified.
- The information needs and measures are identified for the object.
- The procedures and protocols for collection, analysis, reporting are identified.
- The information product and measurement process are evaluated according to a defined criteria.

**Perform the measurement process**: This step consists of integrating the procedure, data collection, data analysis to develop information product and communicating the results.

**Evaluate measurement**: This step consists of the evaluation of information product and measurement process and identification of potential areas of improvement.

**ISO/IEC 9126**

This standard is related to software product quality according to three different views as stated below:

---

**Weighted Sum Product Model (WSPM)**

- **Ease of Use**: The ease of use of the software is determined by the number of errors identified by users.
- **Reliability**: The reliability of the software is determined by the number of failures experienced by users.
- **Maintainability**: The maintainability of the software is determined by the number of changes required to fix defects.

**Goal-Question-Metric (GQM) Model**

- **Goal**: The goal is to improve the quality of the software.
- **Question**: The question is how to measure the quality of the software.
- **Metric**: The metric is determined by analyzing the software and identifying the factors that affect the quality.

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**Contextual Judgment Model (CJM)**

- **Contextual Judgment**: The software quality is determined by the user's perception of the software.
- **Judgment**: The judgment is made based on the user's experience with the software.
- **Quality**: The quality is determined based on the user's satisfaction with the software.

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**Integrated Quality Model (IQM)**

- **Integrated Quality**: The quality of the software is determined by integrating the results from the WSPM, GQM, and CJM models.
- **Model Integration**: The models are integrated by applying the methods and techniques from each model to the software.
- **Quality Assessment**: The quality of the software is assessed by applying the methods and techniques from each model to the software.
• **Quality in use:** The capability of software product to provide the functionality, according to user expectations.

• **External quality view:** The properties of the software product that can be identified when it is operational.

• **Internal quality view:** The properties of the software product that are measured during the implementation of software product.

The quality in use depends on the external quality of the software product. Similarly, the external quality depends on the internal quality of the software product. The measurement of internal quality of software is first step in defining external and existing quality of the software product. The internal and external quality models have the six common quality factors which are also defined in the ISO/IEC 912. These quality factors are related to functionality, efficiency, usability, reliability, maintainability and portability [29]. There are three types of quality metrics that can be used for the measuring the software quality i.e. internal metrics, external metrics and quality in use metrics. The internal metrics are independent of the execution of the software product. The external quality metrics are related to the behavior of the software product while it is running. The quality in use metrics are used for measurement when the software product is ready to use [30].
2.4 Summary and Analysis of the Literature Review

The purpose of systematic review is to provide more structured way to make an assessment, identification and interpretation of research which is relevant to the specific research questions. It is done to determine the current status of research regarding measurement programs and goal definition (according to our research questions) from 01 Jan, 1997 to 01 Mar, 2009.

There were two research questions at the start of this literature review:

**RQ1:** How do organizations use software measurement programs and what are the success factors in software measurement program?

The RQ1 was divided into two parts so that independent searching and analysis could be done on both parts. These sub-questions were:

**RQ1-a:** How Organizations use software measurement programs?

**RQ1-b:** what are the success factors in software measurement program?

**RQ2:** What are the models, frameworks, tools and standards developed for measurement programs?

The first part of RQ1 is related to the ways measurement program are being used, the research study shows that measurement program can be used in monitoring, controlling, decision making, software process improvement, organizational health and performance improvement. The mentioned areas are related to organizational management perspective, SDLC, software process improvement, and they can be used to realize the relationship between the measures/entities of software process, product and resources. The main aim of every measurement program is first to control the processes and as the maturity of the measurement program improves it can be used for the improvement of the overall quality of the measurement. So any organization that needs to improve the process areas can use the measurement program. Similarly, if an organization is not getting the required output in the areas of software products, processes and resources, they can use the measurement programs to collect the data and analyze the results. The first step of measurement programs is to assess the situation, then control and then using it to implement the improvement processes.

The second part of RQ1 is related to the success factors of measurement program. There are research studies in which different factors from different organizational perspectives are discussed. The measurement programs help the managers in identifying the success factors for an organization and areas of improvement on the basis of collected data analysis. In the systematic review those success factors for the measurement programs are identified that can help to utilize the measurement program for best of its purpose. Following are the important success factors:

- Well defined goals, questions and metrics.
- The presence of a structure (well defined structure, flow and connection between the measurement activities)
- The well-defined tasks, activities for data collection.
- Traceability of the measurement goals within the measurement program.
- Traceability of the measurement goals with respect to business goals
- Well-Defined way of data collection
- Well-Defined way of data analysis
- Tool support in data collection, storage and analysis
- Understanding of the objectives of measurement processes
- Measures repository
- Re-usability of measurement objects i.e. goals, questions, metrics, analysis results of previous measurement processes
- Communication and feedback

The identification of the success factors for a measurement programs for an organization can help in improving the measurement programs. One of the ways can be a definition of the measurement goals, questions and measures in a systematic and structured way. The definition of measurement steps in a structured way can help in generalization of the data. There will be an ease of generalization, as that data collection is goal oriented and it’s collected in a structured way so the data collected for one project can also be re-used for another project for a same kind of questions and goals.

The RQ2 is about the role of measurement program in the organization to improve the overall quality of the organization. The rationale behind analyzing different models is that every measurement program uses a measurement model or measurement tool. So the more efficient is the model or tool the more efficient will be the measurement program. The success of the measurement program also depends on the structure of the organization, Software Development Life Cycle and business goals.

In a measurement program, there is need of top down approach to cope the problems and limitations in the bottom up approach. The GQM approach is a goal driven approach that operates in top down fashion. There are many models e.g. GQIM, GAM, QIP, MIS-PyME, AMI that are designed to overcome the deficiency in GQM model, following the basic idea of Goal, Questions and Metrics. The GQM model is also used as a basis for the development of tools and techniques e.g. MPSP, M2P, Primer, for the measurement program.

Every measurement program uses a model/framework, tool, technique and/or standard to define the structure of its tasks, activities and processes. So the effectiveness of the measurement program depends on the effectiveness and precision of the measurement method used. An effective measurement program not only provides the true value of the object (product, project, resource) under study but it also provides the areas where the improvements can be made. The data provided by the measurement program can be analyzed and interpreted to check not only the maturity of the processes of an organization but also measurement programs. This can improve the overall quality of the organization.

The research analysis provides the following ideas:

- There is not a well-defined way of defining the goals, questions and metrics in a structured way.
- The traceability of the goals and questions is not being considered in any research study. The traceability not only provides a version control but it also provides the way of making the connection between the measurement goal and business goals.
- The chances of success of the measurement program can be improved by prioritization of the critical goals and handling them with increased monitoring and control.
- There is need of measurement model that define measurement goals, questions and measures in a structured way. This will not only help in definition of goals, question and metrics as the measurement personnel will be aware what are the properties, e.g. issue, purpose, measurement attributes, he needs to define for a goals, questions and measures. The models e.g. GQM, GQIM, GAM are not defined in way to help the organization to automate them in the form of tool to save time, cost and enhance reusability.
- There is lack of research regarding the re-usability of goals, questions and measures.
3 SPGQM (STRUCTURED PRIORITIZED GOAL QUESTION METRICS)

Software engineering organizations initiate measurement programs to create a corporate memory which could be used to understand, control, assess and improve their processes and products. However, most of these organizations have difficulties in deciding which measures to collect since there is no universal set of measures for all types of organizations and projects.

Based on the literature survey results, we found out that goal oriented measurement programs can be more successful. According to [3] software measurement programs usually fail after implementation in a software development process. In [6], 50-80% of the measurement programs fail after a year due to different reasons. The most important reason of the failure of the measurement programs includes the lack of appropriate knowledge available in order to gain the required measures and/or too abstract goals [2].

The failure of the software measurement program depends on different factors relevant to product, process and resources [2], [3]. According to [11], software measurement programs usually fail as they require expert judgment for selecting appropriate number of measures in relation to the organizational goals. The mapping of goals with appropriate measures requires experienced resources in the field of software measurement. The measurement goals are defined in order to evaluate the progress according to organizational business objectives.

Therefore, software organizations also require selecting minimum set of measures by prioritizing them based on the importance and priority of the goals of the organization as well as the cost associated with measurement to help achieving those goals. This requires a holistic approach with structured goals definition and prioritization processes. However, there is no standard way of defining the structure, quantity and syntax of goals and questions that can guide prioritization and tracking of goals.

One of the aims of our study was to identify the success factors for a measurement program. In the RQ1 (b), we have discussed the success factors of an organization and the reasons of failure of measurement programs including lack of structured definition of goals, questions and metrics. The measurement programs fail due to lack of prioritization of the measurement goals, tool support, measurement repository and re-usability of measurement objects.

The aim of our study was to develop a measurement model that could be implemented in an organization. Therefore different models and tools (implementation of the measurement model) have been analyzed in RQ2. Our aim was to build a framework therefore we considered all the relevant models, frameworks, standards so that we can combine the good aspects and avoid the factors that cause problems in improving overall quality. Goal Question Metric (GQM) [5, 22] is one of the most widely known and used goal oriented model used in the measurement processes. GQIM [23] and GAM [13] are also goal oriented models that were designed to overcome the deficiencies in GQM. We have used the concepts of GQM, GAM, GQIM and other models and tools to design the templates for goals and questions. However, OMSD is used for getting optimum set of measures for questions of a sub-goal and goal.

In our study, we propose a framework, an extension of GQM approach, which aims to fulfill the above mentioned requirements for measurement programs in the organizations. Basically, this framework is a combination of two models developed in Blekinge Institute of
Technology; SPGQM (Structured Prioritized Goal Question Metrics) model and OMSD (Optimum Measures Set Decision) model.

The purpose of SPGQM is the derivation of measurement goals and questions according to the organizational perspective. The measurement goals and sub goals are defined in a structured way so that they are easy to define, communicate, monitor and traceable. The questions are also defined in a structured way to provide consistency, clarity and ease of derivation of measures from them. The questions can have horizontal as well as vertical dependencies between them. The horizontal and vertical dependencies are defined to cover all the aspect of relationship between the goals and questions and within questions [13].

The attributes identified in the questions are later on used for the selection of measures. The measures will be stored in the measures repository of the organization that will increase in its volume with the passage of time. In order to start the measurement process the set of measures for the organizations can defined on the basis of CMMI, ISO 9126 or any standard use by the organization having the measurement guidelines.

The decision making about the final set of measures is taken on the basis of analysis of factors i.e. cost, resources, importance, etc defined in the OMSD (Optimum Measures Set Decision) model for the measures. There will be specific set of questions for each measurement goal and later on with the help of OMSD model optimum set of measures for each question can be defined. The cost of measures for each question relevant to a goal will be accumulated to calculate the cost of implementing that goal.

In the end the goals will be evaluated for their benefits against their calculated cost. So the goals will be prioritized on the basis of cost and benefit analysis and risk analysis, as SPGQM works in both directions i.e. first top down and then bottom up. The prioritization of the goals will help in improving the effectiveness of measurement program. It will also help in identifying those goals that can directly affect the success of measurement program by doing cost and benefit analysis. The analysis of these goals will later on help in identifying the success factors for the measurement program in an organization.

The structured definition of goals and questions is merged with OMSD model to make a model. The primary purpose of OMSD is optimization of the measures. In, SPGQM we have used it for the optimization of the measures and later on prioritization of goals on the basis of cost, importance and frequency of optimized measures for each goal. The combination of structured goals, questions and OMSD forms SPGQM. The goals, questions, measures are defined in a top-town way then later on goals are prioritized on basis of factors relevant to measures in bottom-up way.

**SPGQM (Structured Prioritized Goal Question Metrics) Model**

The SPGQM is an Extension to GQM (Goal Question Metrics). The research study revealed us that GQM is most widely used and known model. So the extension in GQM is easily understandable for the reader. The GQM has three major parts goals, questions and metrics. The goals and questions are provided in the same flow as GQM but there is a way provided with the help of templates to define them in a structures way. The final part of GQM is metrics selection for questions. We have used Optimum measures decision set model (OMSD) to not only identify the measures but later on optimize them as well. So the basic theme of GQM i.e. goal, question, metrics is same but they are refined to used them in an efficient way.

The templates provided in sections, (3.2.1, 3.3) below provide the definition of goals questions in a structured way. The SPGQM uses the idea of measurement repository that can
be developed using the measures defined in CMMI, ISO, and measurement models. It was aimed to develop SPGQM in a way that it can be easily automated with a measurements repository according to the needs of the organization, as the goals, questions and metrics have a well-defined structure, definition and flow. The OMSD model is used for the prioritization of the measurement goals on the basis of optimized measures. The SPGQM aims the use of following success factors relevant to goal oriented measurement:

- Structured definition of goals and question.
- Traceability of the goals, question and measures.
- Optimum set of measures.
- Supporting re-usability of structured (goals, questions) and measures.
- It can be easily automated according to the needs of organization.
- Prioritization of goals on the basis cost, frequency and usage of measures against the benefits.
- Structured definition (of goals and question), optimization of measures and prioritization of goals for successful measurement programs.

**Note:**

We have used the GQM [5, 27] as base model for extension. The conceptual level of GQM is covered with the help of considering the organizational perspective and structure definition of goals. The operational level is covered with the help of structured question definition. The post meeting analysis is used between goal definition, question definition, measure selection and goals prioritization processes in SPGQM. The quantitative level is replaced with the help of OMSD [46] model. So we have used an already build model i.e. OMSD [46] for measures selection and optimization to build a framework SPGQM. We have not provided the structured definition of goals and questions separately as there will be no use of it separately as the measure selection (to answer the questions) and measures optimization is done after it. The goals prioritization on the basis of optimized measures is done at end. So it’s useful as a whole to define goals, question and measures and then prioritize the goals in the form of a framework i.e. SPGQM.

**SPGQM (Structured Prioritized Goal Question Metrics)**
Figure 3.0: SPGQ
3.1 Organization perspective analysis

In this step the following factors are identified because they can affect the measurement program [24].
- Organizational business goals
- Benchmarking data of products
- Stakeholder’s point of view

![Organizational Perspective Diagram]

Figure 3.1: Organizational Perspective

The organizational business goals are used to derive the measurement goals in a measurement program [17, 40], as these business goals are extracted from Business Plan document. The benchmarking data of the products can also help in defining the measurement goals for the improvement in the product. The customer value analysis is one of the methods that can be used to analyze the product with respect to similar other products in the market [47]. The functionalities of products are compared with respect to the customer needs and expectation. The rationale behind using the customer value is its ease of use. A point system can be used to give the points to all functionalities that a software product provides. The customer value is used for the products that are being developed by the different organizations for a set of customers [47]. The stakeholder point of view can provide the possible dimensions and detailed insight for definition of measurement goals [24].

3.2 Structured goal definition phase

In the structured goal definition we have used a template to define the goals and sub goals in an iterative way. The figure 3.2 shows the structured goal definition phase.
In this step the goals are identified according to “Goal Definition Template” (containing the attributes of the goals) that can help in structure goal definition [22]. In [22], purpose, issue, stakeholder’s information need, scenario, and relevant entities are stated to be included. We also included the concept of “Information needs to track” from [12]. We also included goal category i.e. product, process and resources, as this concept is taken from [2], [3].

In our “Structured Goal Definition” template, we used requirement engineering concept [47] in order to make goals traceable and track information by including Goal Identifier, Version, Description, Author, Relevant Business goal, and primary measurement goal. These attributes will be described below in order to make understandable. Following figure 3.2.1 shows the template for structure goal definition form.

<table>
<thead>
<tr>
<th>Structured Goal Definition Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal Identifier</td>
</tr>
<tr>
<td>Description</td>
</tr>
<tr>
<td>Author</td>
</tr>
<tr>
<td>Purpose</td>
</tr>
<tr>
<td>Issue</td>
</tr>
<tr>
<td>Category</td>
</tr>
<tr>
<td>Stakeholders for information need</td>
</tr>
<tr>
<td>Scenario/ Environment</td>
</tr>
<tr>
<td>Relevant Entities</td>
</tr>
<tr>
<td>Information needs to track</td>
</tr>
<tr>
<td>Relevant business goal</td>
</tr>
<tr>
<td>Primary Measurement Goal</td>
</tr>
</tbody>
</table>

Figure 3.2.1: Structured goal template

Following is the description of the attributed of the structured goals:

**Purpose:**
It is an attribute of a goal which will describe a reason to study an object e.g. to analyze, to increase, to predict etc.

**Example:**
To analyze the productivity of testing team for a product, where analyze (analysis is the purpose of the goal).
Issue: 
An issue is a property of an object i.e. project, process or resource to be studied. The issue is an important property which helps in identifying the metrics required to answer the achievement of goal.

Example: 
To analyze the productivity of the testing team for a product, where productivity is an issue. An issue can be analyzed with the help of different metrics like number of bugs, number of test cases.

Category: 
The goals are categorized with the help of this template which will save the time for categorization later on. The categorization of the goals is done on the basis of literature review. The ‘other’ field is provided to reduce the chances of sticking only to these categories and identifying the new category if it’s required in future.

Stakeholder for information need: 
The stakeholders are the personnel that can be internal or external. The internal stakeholders are the personnel who are associated with the measurement program or other parts of the organization. The external stakeholders can be customer, government agencies etc.

Scenario/ Environment: 
The scenario/context is the environment in which measurement is to be taken place e.g. software design, development or testing. This attribute will also help in understanding the measurement process in context of different phases of different software development life cycles.

Relevant Entities: 
The relevant entities are the objects which are going to be analyzed. The relevant entities can be deliverables or work products in a software development life cycle. For example the work products can be SRS, design document, software product, and test cases.

Information needs to track: 
The concept of information need is taken from measurement information model. The purpose of information need is to look for necessary information that is required to track the measurement goals. For example, to analyze the productivity of measurement goals the information need can be in the form of function points, source lines of code, number of modules etc.

Relevant business goals: 
The relevant business goals are provided with the measurement goals to analyze measurement goals according to the business goals. This also provides the traceability of the goals with respect to business goals. The literature shows that [12, 24] it’s a good approach to derive the measurement goals from business goals.

Primary measurement goals: 
There can be different dimensions (sub-goals) of a measurement goal; therefore, it is good idea to define them as sub-goals. E.g the measurement goal of reliability can have sub-goals relevant to likelihood of failure and failure of function. So this attribute of structured goal definition provides the dependency and relationship between the primary measurement goal and its sub-measurement goals.
Traceability information
The traceability information are added to each goal so that modification in the goals are recorded and the original version of the goal definition is also maintained to monitor the deviation in goal definition and goal achievement during and at the end of the measurement program. The traceability information includes:

- Identifier (the identifier must be unique)
- Author/source
- Description
- Version

Identifier:
The purpose of the identifier is to allocate a unique value to each measurement goal. The idea of unique identifier is taken from the Requirement engineering [47]. The unique identifier will help in making the goals uniquely identifiable and will help in making the measurement goals traceable. The identifier property of the goals can contain the value so that it contains the project id and goal id e.g. itslearning-usability-01, where itslearning is project name and usability is the relevant goal.

Author/source:
The author/source is a person in measurement program that has documented the measurement goal so that in future if there is an ambiguity it can be clarified. In most cases it might be a person relevant to measurement process.

Description:
The description might contain all the details that are required to for the measurement program needed to be documented.

Version:
The purpose of the version attribute is to provide the traceability in the measurement goals. There is a possibility that in long term measurement program the measurement goals are modified so there is a need of a mechanism to track the changes. So the changes in the measurement goal can be traced with the help of version attribute of a goal.

Note: The finalized structured goals contain identifier, author, description and version.

Identification of dependencies and sub-goals
The sub-goals of the primary goals are identified with the help of identification of dependencies between the goals. The identification of primary goals and sub-goals is an iterative process. The template used for identification of primary goals is also used for the definition of sub goals.

3.3 Question Definition Phase
The questions relevant to each goal are defined in a structured way. The template for the structured question definition is shown in the following diagram.
Figure 3.3: Structured Question Definition Template

**Associated Goal(s) identifier:**
The question is identified according to the goal. If a question has a vertical dependency for more than one goal then in this template all the relevant goals will be documented. The associated goal identifier field is used to document all the relevant goals identifiers.

**Question identifier:**
Each question has a unique identifier for traceability.

**Issue:**
The issue is the attribute that is going to be analyzed or calculated with the help of measures. The repetition of issue attribute in the question template is due to the reason that issue described in a goal can have more than one sub issues.

**Entity:**
A specific entity/object whose attribute is going to be measured. A goal can have more than one entity but at the question level the specific entities that are needed to be studied are documented for entity attribute.

**Description:**
The description field contains the overall description of the question.

**Stakeholders:**
All the relevant personnel those are associated with the question. The stakeholder helps in covering all the required dimension of needs of stakeholders relevant to the question.

**Scenario/context:**
The scenario/context is the environment in which measurement is going to be taken place.

**Horizontal dependency:**
The horizontal dependencies between the questions are identified with the help of writing the unique identifiers of questions that are dependent.
**Horizontal and vertical dependencies**

The *horizontal dependencies* are within the questions. The question A is horizontally dependent on question B, if the answer of a question B is to be reused to complete the answer of question.

There is a possibility that one question may be needed for more than one goals, such situation is called *vertical dependency* between goal and questions. The associated goal identifier attribute can contain more than one measurement goal IDs if there is more than one vertical dependency [13].

**OMSD (Optimized measurement set decision set model)**

The OMSD model is used to replace quantitative level of GQM. It not only helps in identification and selection of measures to answer the relevant questions but it also provides the optimization mechanism of the measures.

The OMSD model has five main steps:
- Selection of a question category.
- Identification of the attributes to be measured in the questions.
- Selection of measures from the measurement pool or using the measures defined in a standard.
- The development of factor and attribute tables with the help of data collection
- Decision making by using heuristic approach to select optimum set of measures

![OMSD Diagram](image-url)

*Figure 3.3.1: OMSD*
3.4 Post meeting analysis

The post meeting analysis is an important part of the SPGQM. It is used in the following ways:

- Preparation of potential goals, questions and measures before the actual process.
- Reviewing and finalization of work done.
- Preparation of facts and figures for decision making in goal prioritization.

Post meeting analysis also the following activities which will be used in the decision making for prioritization of goals (see Figure 3.4);

- Cost-benefit analysis [12].
- Risk analysis.

**Cost and Benefit Analysis**

It is an informal approach for decision making but in our case we are using OMSD model as a basis for it. Each goal has a set of question and measures; the OMSD model is used to calculate the cost of optimum set of measures. The cost of measures for a goal is used in the analysis against the overall benefits of the goal. It helps the measurement responsible in prioritization of the goal. This approach aids in making the prioritization on the basis of cost, frequency, importance, usage of measures against benefits of goals which make task of goal prioritization less error prone.

**Risk Analysis**

The potential risks to the measurement process are identified on three main factors i.e. time, cost, resources. Each risk will be associated to a category i.e. Low, Medium and High on the basis of expected level of severity of the risk. The values 1, 3 and 5 will be used respectively for Low, medium and high risk category. Following is the Template that can be used for the risk analysis of the measurement goal.
### Table 3.4: Risk Analysis

<table>
<thead>
<tr>
<th>Goal ID</th>
<th>Risk Factor</th>
<th>Description</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 3.5 Prioritization meeting

In the prioritization meeting (see Figure 3.5), first of all the results of the post meeting analysis are presented. The results help in making the prioritization less conflicting and less time consuming. The 100$ method is used for the prioritization of the goals. In this method each stakeholder (internal and external) distributes 100 points among goals according to their importance and cost. The goals with the higher value have the higher priority. In the end, mean of the values (given to the goals by all the participants) are calculated [13].

![Figure 3.5: Prioritization Meeting](image)

The rationale for using 100 dollar method is the ease of its use and it does not require any training. Another reason for using 100 dollar method is the availability of information in the appropriate form, as the cost of each goal, its risks and benefits are available before making the decision and distribution of points among them. The usage of 100 dollar method here is to prioritize the goals on the basis of available facts and figures.
4 CASE STUDY

4.1 Case Study Design

The purpose of SPGQM is to implement a measurement program in an organization to access, analyze and improve the overall quality of the organization with the help of structured goal oriented measurement. In order to validate the model, we conducted a case study. The figure 4.1 shows actual case study that we have done in collaboration with the company. Measurement team (authors of this thesis and two other MSE students of BTH) has done the Post Meeting Analysis.

Figure 4.1: Case Study Design
4.1.1 Case Organization

The company ‘A’ is an IT-based company established in 1987 in USA, provides IT-based solutions and services around the globe. Main IT-based solutions involve warehousing, software development, modification and maintenance. The company provides telecommunication, human resource management and financial management services. Most of the projects in the company range from 6 months to more than two years. The company is currently CMMI® Level three.

4.2 Case Study Conduct

We have conducted a case study by conducting interviews with different responsible personals in the company ‘A’. These interviews are divided into five parts (see section 4.3). these interviews are consisted of open-ended and close-ended questions, in order to get particular information. Case study has conducted as it designed to be conducted (see figure 4.1)

4.3 Initial interview

In the start, we conducted an interview with an interviewee ‘X’ in the company ‘A’ to collect the basic information. The interviewee is a software engineer and has five years experience of project management in the company. The reason for choosing a project manager was to get the information about the running projects, processes and resources of the company as well as relations and dependencies between them. The interview consisted of open-ended and close-ended questions (see Appendix A). The interview composed of five parts.

First part of the initial interview was to know the interviewee. The second part was to understand the organizational infrastructure. The third part of the interview was about knowing and understanding the measurement process of the company. The fourth part was about introduction of SPGQM model along with the examples of structured goals, question and OMSD model. The fifth part of the interview was about selecting projects according to the time and feasibility for the implementation of case study in research time. The business goals for the selected projects were finalized after the selection of projects at the end.

4.3.1 Organizational perspective

During the interview, we identified the ‘organizational perspectives’ in the case company ‘A’. The business analyst, project manager and team leader are the responsible persons for all the communication with the customer at the initial level of the project. These three personal have three different perspectives when they meet the client. The project manager considers things according to overall project management perspective. The business analyst considers things according to the business benefits that a company can have. The technical team lead look after at the lower level of management. The technical team lead knows about the availability, skill level of the resources. However, team lead knows the technical complexities and risks at the lower level. This makes understanding the things right and doing them rightly from the start.

The software development life cycle (SDLC) of the company is shown in the following figure 4.3.1.
4.3.2 Case Projects
We collected the Software Requirement Specification of two projects to use during the implementation of SPQQM. We studied those to comprehend the domain, qualities and the goals of software product development. One of the most important aspects was to learn how the goals are defined for a software project.

One of the projects is related to the E-banking. Its duration was more than 2 years. We were provided with the Software requirement Specification of one of the module that was developed in six months. The reliability was selected as the primary goal for the measurement process.

The second project was E-management system. Its duration was six months. The software requirement specification for all the requirements was provided. The maintainability was selected as the primary goal of measurement.

The rationale behind choosing the short term projects was that have been previously done was to conduct the case study within the available time and resources.

4.3.3 Measurement process
The measures used in the company are at a basic level as it means that they only use measures for the general software development activities but not the minor ones. The measures which are collected by the company are mostly related to project management such as time, cost, size of the product (function points), errors found, and errors corrected. The other measures of the measurement program vary from project to project.
4.4 Data collection

The data collection during the case study was done with the help of interviews and meetings. The initial information about the company was collected with the help of an interview (APPENDIX A) with the project manager (section 4.3). The data collection about the structured definition of goals (APPENDIX B) was done in a meeting (section 4.4.1). The data collection about the structured definition of questions (APPENDIX B) is done in a meeting (section 4.4.2). The data collection about optimum set of measures and prioritization (APPENDIX C) was done in a second meeting (section 4.4.5, 4.4.6).

4.5 SPGQM Implementation:

We sent the executive summary to the company ‘A’ before conducting the case study. The executive summary included the working of the SPGQM and how case study can be done in the company. Later on, we sent different examples of defining the goals and questions. These examples contained goal definition for project, process and resources. The example about the OMSD application was also provided to the company. This was all done before the initial interview. During the interview the area that need more clarification were clarified to the interviewee.

4.5.1 Goal Definition Meeting

We studied the SRS and business goals of selected projects, company website and initial interview before conducting the goal definition meeting. This helped us to define the possible areas for which the goals can be defined for the measurement. During the preparation of goal definition meeting, we analyzed,

- The organizational background/Perspective
- The business goals (from initial interview)
- The measurement sub-goals (from SRS)

There were six participants in the meeting. The attendees of meeting from the company include:

- Project Manager.
- Business Analyst.
- Technical Team Lead.

Two authors of this thesis and two other students of BTH (working on the automation and improvements of SPGQM) were present at the meeting. Two of the students were having moderator role. One student was recording the goal definition process by filling in the templates of the goals on Google docs. One of the students was making the review of all the defined goals on Google docs. The recording of the meeting proceedings i.e. structured goals provided to all the participants.

The meeting was divided into two sessions. Each session consisted of 45 minutes to define the sub-goals for one of the two projects, as the primary measurement goal for each project was initially selected. The sub-goals for two primary measurement goals were finalized in the meeting. At the end of goal definition meeting, three sub-goals for each measurement goal were finalized.

Note: The primary measurement goals were derived from the business goals (the business goals for each project were defined by the project manager in initial interview. The structured definition of the goals is provided in Appendix B.
4.5.2 Post meeting Analysis:
The post meeting analysis was done by four students of BTH. The purpose of this analysis was to define the potential questions and measures for the finalized goals. The reason for defining the structured questions and measures was to cope with restriction of limited time, as it helped later on in questions and measures identification in timely and affective way.

The post meeting analysis has two main parts; in the first part, the goals defined with the help of structured goal templates in the first meeting were reviewed and the set of potential questions were defined for each goal.

In the second part, the measures for the potential questions were selected by the measurement team of BTH students. The information collected in the initial interview about measurement process helped to identify the potential measures. The templates were prepared for structured questions for both projects. The forms for structured questions, factor mapping, attribute mapping and goal-prioritization were made available on Google docs so that everyone can view the updates.

4.5.3 Structured Question definition and OMSD implementation meeting
The second meeting was divided into two main sessions, structured question definition session and OMSD implementation.

4.5.4 Structured question definition session
The structured question definition session was divided in two sub sessions. The potential questions for each project and measures were defined in the sub-session. Each sub-session was consisted of 45 minutes. The set of potential questions and relevant measures already prepared helped to do the task within the limited time in a better way. There was a break of 10 minutes to review the work and prepare for next session. The set of questions finalized in the meeting are given in APPENDIX B.

Note: The preparation of set of potential questions before the structured question definition prompts the idea in the mind of the reader that these questions were only defined by the BTH measurement team. The potential questions were prepared to fasten the thought process as the new questions were also defined and potential questions were also rejected and modified. The structured questions were finalized in negotiation between the BTH measurement team and company personnel.

4.5.5 OMSD implementation and prioritization
This part was done in two major sessions. Each major part had two sub-sections. In the first sub-section for each project the set of selected measures for each goal were mapped on to a factor table. Later on, the attribute mapping was done for the measures to know the important attributes for each measure that can help in decision making on the basis of available budget, importance and usage of the measure. The similar process was used for the measures of both the projects. The Factor table, and Attribute table for measurement mapping and prioritization form are given along with the prioritization of the goals for each project in the APPENDIX C.

4.5.6 Prioritization
The prioritization of the goals was done at the end of each OMSD implementation session. The participant from the company has been assigned different roles for the prioritization. The project manager was responsible for the goal prioritization on the basis of user perspective. The Technical team-lead of the project was responsible for the goal prioritization for the organization perspective. The business analyst was asked to prioritize
on a general level. The average of all the priorities was taken at the end to have final value of priorities for each sub goal.

A similar process was used for the prioritization of goals for both the projects at the end of the implementation of OMSD meeting. The tables used for prioritization are provided in the APPENDIX C.

4.6 Case Study Results Analysis
The analysis of the case study is to know advantages, shortcomings and limitations of SPGQM. The data collection for the case study is done in the form of interview and meetings. The analysis of each part of case study is done in the same orders as it was conducted.

4.6.1 Initial interview
The initial interview was conducted with the manager of software development department. The interviewee has five years of experience. The interview was divided in four parts.

Interviewee introduction
The purpose of first part of interview was about knowing the personal as the validity of the answer also depends on the qualification, areas of experience and skills of the personal. The other reason is to know the interviewee before conducting the interview.

Organizational introduction
The purpose of the second part of the interview was to know the infrastructure of the organization. It contains the questions regarding following:
- The types of projects are done by the organization i.e. Market-Driven and Be-spoke, as both involve different type of customers
- The types e.g. technology of projects your organization implement.
- The SDLC(s) use in the organization, as they are important to know from the measurement processes because different processes require different measures.
- The business goals definition process of the organization, as the measurement goals are derived from the business goals of the organization.
- The standards and models used for software development and organizational management.

4.6.2 Measurement Processes
The purpose of the third part of the interview was to collect the information about the measurement program. This information was required to design the research case study to be implemented in the organization. In this part the questions regarding the following areas were asked:
- Information about the measurement department, as if the company has this department, there are more chances of its maturing in measurement process.
- The definition process of business goals for the projects and products as the measurement goals are derived from the business goals.
• The information about how the measurement process is being followed in the organization, as there is a need of measurement process to collect the measures in a better way.

• The information about how the measurement data is being collected as if there is formal data collection process does not collect the data in a better way.

• The information about the configuration of measurement program in a SDLC as the measurement process runs parallel with the SDLC.

• The information about the types of measures collected in a project as it shows the level of maturity of measurement process in organization.

• The information about how the collected data and measures are used for the sake of improvement in the organization. however, one of the main purpose of measurement is to control and improve the processes of the organization in order to improve the overall quality.

• The information about different data collection techniques used, as it affects the validity of the data and its usability.

• The information about how the software measurement processes are tracked because we cannot measure until we can control.

4.6.3 Project selection
The purpose of this part of the interview was to select the projects relevant to be-spoke and market-driven respectively. The reason behind the selection of both types of projects was the influence of different stakeholders. The development of these projects involves different measures and different processes.

The basic information about the projects was collected i.e. software product, cost, time, resources, measures used, SDLC and business goals for one area to measure.

There were two projects and there only two areas of measurement were defined. The business goal for reliability and maintainability were defined in APPENDIX B. The literature review for measurement program showed that measurement goals must be derived from the business goals. That is the main reason of selecting manager in order to define the measurement goals for maintainability and reliability for a bank project and e-management system respectively.

4.6.4 Preparation for the goal definition meeting
The initial interview helped in understanding the organizational SDLC, measurement processes, resources utilization for projects and processes. The business goals defined in the initial interview which helped in derivation of the measurement goals. The basic information about the project was available so it was easy and efficient to define the potential areas of measurement along with the measurement goals.

4.6.5 Goal definition meeting
The number of potential areas and the measurement goals helped a great deal in finalization of the measurement goals. There were 8 potential sub goals defined for the maintainability and 6 sub goals for reliability. Each project was given 45 minutes for Goals definition. Google docs were used for the structured goals definition as the updated were available to everyone. Those goals on which project manager and one of the two personals of business analyst and technical team lead were agreed were finalized. The analysis of the Goal definition meeting showed us following:
The analysis of the Goal definition meeting showed us following:

- The use of structured goal definition makes the task of brainstorming easy.
- It also provides the reusability of the goals as they are documented in a structured way having the purpose, issue, stakeholders, version, identifier and category etc APPENDIX B.
- Once the goals are defined they can be used for different products with minor changes, like goals for maintainability will contain same issues, purposes for various projects.
- The measurement goals derived from the business goals helps the tracking of achievement of business goals.
- The structured goal definition makes the aim and objectives of the measurement program clearer.
- If the measurement personnel can define the potential measurement goals then they can be finalizes with ease involving other personal. E.g. project manager, business analyst.

4.6.6 Post meeting Analysis
In the post meeting analysis, the measurement goals were finalized after reviewing to move towards questions. The set of potential questions regarding the measurement goals were prepared along with the measures. The purpose of preparation of measurement questions was to utilize the limited time for question definition in the second meeting. The set of measures relevant to questions were prepared later on in the post meeting analysis. Tables for factor mapping, and attribute mapping were developed by using Google docs in the end of post meeting analysis. The reason of doing all the work before the meeting is to save the time and maximum time is used for decision making.
4.6.7 Question definition and OMSD implementation meeting:
The second meeting has two major parts, one of them was relevant to question definition for both the projects in APPENDIX B and the other one was relevant to implementation of OMSD. The question definition session was divided into two sessions. The questions for the goals of each project were defined in each section.

4.6.8 Questions for sub-goals of reliability
The first session of the question definition meeting took 45 minutes long. The questions for sub-goals were defined for the reliability project. The questions for each sub-goal were finalized as there were three sub-goals finalized for reliability. The finalization of the question was on the basis of agreement on inclusion of question by the manager and at least one of the business analyst/technical team lead.

For reliability sub-goal G1.1 there were three potential questions presented. Three potential questions were finalized without any modification and one question was newly defined. The major area of concern for all the goals was software failure, so at the end, four questions were finalized after the discussion.

For reliability sub-goal G1.2 there were five potential questions presented and two potential questions were finalized without any change and 2 questions were reshaped/re-structured (with changes in issue, purpose, stakeholder, etc) in the meeting. There were four questions finalized at the end of meeting.

For the reliability sub-goal G1.3 there were six questions presented and there were two potential questions finalized without any change. One question emerged in the meeting. One question was reshaped/modified. There were four questions finalized in the meeting.

The graph in figure 4.6.8 shows that potential questions proved useful as few of the potential questions were accepted during the question definition process and some of them were modified. So it not only helped in utilizing the limited time in an effective way but at the same time they were finalized by the business analyst, project manager and technical team-lead by either modifying them or accepting them without any changes. The new questions were also defined in the meeting when it was considered that some areas of the sub-goals were missing.

![Figure 4.6.8: Graph related to Reliability Goal](image)

4.6.9 Questions for sub-goals of maintainability
The second session of the question definition meeting was 45 minutes long. In this meeting, measurement questions are defined for sub-goals for the maintainability project. The questions for each sub-goal were finalized as there were three sub-goals finalized for reliability. The finalization of the question was on the basis of agreement on inclusion of question by the manager and at least one of the business analyst/technical team lead.
For maintainability sub-goal G1.1 there were six potential questions presented and out of which there were two questions finalized without any change and one question was originated in the meeting. One question was reshaped/modified. At the end, there were four questions finalized.

For maintainability sub-goal G1.2 there were eight questions presented and out of which there were two potential questions finalized without any change. One question was emerged during the meeting. At the end there were three questions finalized.

For maintainability sub-goals G1.3 there were four questions were presented and out of which only one potential question was finalized without any change. Two questions emerged during the question definition process. At the end there were three questions were finalized.

The graph in figure 4.6.9 shows that potential questions proved useful as few of the potential questions were accepted during the question definition process and some of them were modified. So it not only helped in utilizing the limited time in an effective way but at the same time they were finalized by the business analyst, project manager and technical team lead by either modifying them or accepting them without any changes. The new questions were also defined in the meeting when it was considered that some areas of the sub-goals were missing.

![Graph related to Maintainability Goal](image)

**Figure 4.6.9: Graph related to Maintainability Goal**

### 4.7 OMSD implementation

The second major part of second (Question definition and OMSD implementation meeting) meeting was about OMSD implementation APPENDIX C. There were two sub-parts of the meeting, each consisting of 45 minutes for a project. In the first session, the measures for reliability questions were identified, while in the second part, the measures for the maintainability questions were finalized. The goals were prioritized at the end of the meeting. The detailed analysis of these sessions is given below for each session.

#### 4.7.1 OMSD implementation for Reliability measures

The OMSD implementation for reliability measures was done in the first session of the OMSD implementation meeting. Prioritization was done at the end of OMSD implementation meeting. There were four sections of the OMSD implementation.

- First of all the measures for the questions were finalized.
- The second step was to map the measures in the factor mapping table.
- For each sub-goal of reliability the factor values were finalized in the meeting. The third step was attribute mapping in which the metrics were mapped with the measures. The usage and importance of the metrics were calculated. The measures were optimized at the end.
The fourth step was prioritization of the goals on the basis of optimized measures.

4.8 Implementation of OMSD for reliability

The implementation of the OMSD was done according to the steps mentioned in above section 4.7

4.8.1 Factor mapping for Reliability
There were twelve measures selected for first sub-goal G1.1 of reliability in APPENDIX C. There were five measures that were found to be repeating in the other goals later in the measures identification process. There were seven measures finalized for the three questions of sub-goal G1.2 in APPENDIX C. There were five measures for sub-goal G1.2 that were repeated. There were ten measures finalized for four questions for sub-goal G1.3 in APPENDIX C. There were five measures that were repeated. Question no.3 of G1.1 was repeatable in G1.2 and G1.3 as well so its measures were repeating.

4.8.2 Attribute mapping for Reliability
There were total fifteen metrics and nine distinct measures for the Reliability goal. The value of the usage was given on the basis of number of time in which the metrics need to be collected or calculated. The value of importance was given on the basis of criticality of the measure for the achievement of goal.

4.8.3 Optimization of measures
The total cost of all the measure collection was $3155. The assumed available budget for the collection of measure was 2000 and the cost of initially selected measure on the basis of usage and importance was 2780. The OMSD helped more to trade-off between the measures to select the important measures within the budget.

4.8.4 Goal prioritization
The goal prioritization was done on the basis of values of selected measures in the attribute mapping table. The manager was asked to rate the goals on the basis of customer perspective. The technical team lead was asked to rate the goals on the basis of organizational / Technical perspective and business analyst was asked to rate the goals on the basis of overall perspective of customer and organization.

The reason for assigning manager to rate the goals on customer perspective was the more interaction with the customer, level of understanding the needs of customers and knowledge about the customer expectations. The business analyst is the person, who not only looks for having the benefits from the software production and services but at the same time concern with the customer goodwill. The technical team lead is the person who knows the technical aspects of the projects and has the direct interaction with the measurement personnel.

The goal prioritization was done at the end. The reliability sub-goal G1.3 was given the most priority, as it was related to the failure of the software to provide the functionalities. The reliability goal G1.1 was given second priority, as it is related to chances of failure. The reliability goal G1.2 was given the least priority, as it was related to software failure of function. Following diagram shows the priorities of the reliability sub-goals.
4.9 OMSD implementation for maintainability measures

The OMSD implementation for reliability measures was done in the second session of the OMSD implementation meeting and goal prioritization was done at the end of the meeting. There were four parts of the OMSD implementation.

- First of all, the measures for the questions were finalized.
- The second step was to map the measures in the factor mapping table.
- For each sub-goal of reliability the factor values were finalized in the meeting. The third step was attribute mapping in which the metrics were mapped on to the measures and the usage and importance of the metrics were calculated.
- The fourth step was prioritization of the goals on the basis measures.

4.9.1 Implementation of OMSD for maintainability

The implementation of the OMSD was done according to the steps mentioned in above section.

Factor mapping for Maintainability

There were fourteen measures selected for first sub-goal G2.1 of maintainability in APPENDIX C. There were four measures that were found to be repeating (in the goal G2.1) later on the measure identification process. There were ten measures finalized for the three questions of sub-goal G2.2 of maintainability in APPENDIX C. There were four measures for sub-goal G2.2 that were repeated. There were four measures finalized for two questions for sub-goal G2.3 in APPENDIX C. In the last, there was no repeating measure in G2.3 of maintainability.

Attribute mapping for Maintainability

There were total twenty four metrics and nine distinct measures for the maintainability goal. The value of the usage was given on the basis of number of times the metrics need to be collected or calculated. The importance value was given on the basis of criticality of the measure for the achievement of goal.

Optimization of measures

The total cost of all the measure collection was $15025. The assumed available budget for the collection of measure was $7000 and the cost of initially selected measure on the basis of usage and importance was $9251. The OMSD helped more to trade-off between the measures to select the important measures within the budget.
**Goal prioritization**

The goal prioritization was done on the basis of values of selected measures in the attribute mapping table. The manager was asked to rate the goals on the basis of customer perspective. The technical team lead was asked to rate the goals on the basis of organizational / Technical perspective and business analyst was asked to rate the goals on the basis of overall perspective of customer and organization.

The reason for assigning manager to rate the goals on customer perspective was the more interaction with the customer, level of understanding the needs of customers and knowledge about the customer expectations. The business analyst is the person, who not only looks for having the benefits from the software production and services but at the same time concern with the customer goodwill. The technical team lead is the person who knows the technical aspects of the projects and has the direct interaction with the measurement personnel.

The maintainability sub-goal G2.1 was given the more priority, as it was related to the improvement of maintainability process. The maintainability goal G2.2 was given second priority, as it is related to assurance in the maintainability of the process. The maintainability goal G2.3 was given the least priority, as it was related to maintainability of the requirements as the customer requirements may change after the requirement analysis process. Following diagram shows the priorities of the maintainability sub-goals.

![Maintainability Sub-goals Prioritization](image)

**Figure 4.9.1: Graph related to Maintainability Goal**

### 4.10 Effective prioritization by managers

The best aspect of prioritization here is that SPGQM provided all the necessary information to the managers and still the decision is in their hands. The managers make decisions on the following basis:

#### 4.10.1 Cost of Goals

The total cost of each goal is calculated on the basis of resources involves and the amount of time needed to be spent. So the Accumulated cost not only provides the insight about the amount of money required in terms of time and resources involved i.e. the more time and resources involved the more will be cost.

#### 4.10.2 Importance and usage attributes

The availability of the Importance and usage information about the goals makes the decision making more precise and accurate. The decision making about the prioritization of goals can be done on the basis of usage and importance.

The hundred dollar method is selected to be used for prioritization. This method is easy to use and the points can be given to an object on the basis of any attribute i.e. importance, usage and cost. The new attributes can be added to the measure decision making process in...
future and any organization can decide the attributes on which the measurement goals can be prioritized.

4.10.3 Benefits of prioritization

- The prioritization of the goals on the basis of OMSD helps in improving the chances of success of measurement process as the goal which is more critical can be handling with care.

- The prioritization of goals with the help of OMSD is done on the basis of facts and figures and as an outcome the results are more efficient and accurate than guess work.

- The prioritization of the goals can be done on the basis of importance for a critical mission project where the cost for measure calculation/collection does not matter.

- The prioritization of the goal on the basis of structured goals and questions and OMSD helps to improve the decision making in future. The analysis of decisions can be done easily as all the data available regarding goals, questions and metrics will be in structured and organized manner.

4.11 Goals and sub-goal Prioritization

In this case study due to limited time available from the company only one measurement goal was defined for each project. Each measurement goal (i.e. reliability and maintainability) was having three sub-goals. In this case, the prioritization is done at the sub-goal level.

The SPGQM can not only be used for the prioritization of the sub-goals but it can also be used for the prioritization of the Primary/main goals. The prioritization can be done at primary goals level and if it has many sub-goals then they can be prioritize within the goal.

A measurement program can have measurement goals relevant to different categories i.e. product, process and resources. In this case the goals can be prioritized within the same category and/or prioritization can be done between the measurement goals. The main purpose of the prioritization between the primary measurement goals is to improve the chances of success of measurement program. A goal can have many sub-goals and there will be some sub-goals for every primary goal that are very important for the achievement of that goal so the sub-goals for the primary measurement goals can be prioritized to improve the chances of success overall.

Note: we could not manage to do prioritization of the goal and sub-goals against the risk analysis and benefits of the goals due to lack of time available time. It is also mentioned in the future work.
5  VALIDITY THREATS

There are four types of validity threats described by [48], and these are described in the following subsections.

5.1  Types of validity threats

There are four types of validity threats outlined by [48] which are conclusion validity, construct validity, internal validity and external validity.

5.1.1  Internal validity

According to [48], internal validity is an affiliation between the treatment and outcome (results), as it helps researches to depict result from the causes and effects. Internal validity identifies those factors that affect independent variables without the researcher’s knowledge [48], [49]. During the selection of subjects from population also have an effect on the internal validity. Internal validity is also known as causality [48].

In this study, two kinds of threats arose, one of them could have occurred during the systematic review of the studies and the other one could have occurred during the industrial interviews. During the systematic review, different internal validity threats might have occurred. For example, publication bias, as it means author(s) of particular study may mention only positive findings and not specify negative findings [14]. However, usually authors only focus only one aspect of their study and bury other aspect i.e. negative or positive aspects. After systematic review of literature, it is observed that measurement goals derive from business goals by project manager and business analyst. So it can be threat that inappropriate person derive measurement goals from business goals. There is a need of understanding the measurement goals as well before defining the measurement goals, as the measurement goals are used to see the level of achievement of business goals.

Internal validity threats associated with industrial interviews is to select appropriate organization and interviewee knowledge. Authors have problem during the interview because on the second meeting, authors have contacted at Kuwait office of selected company ‘A’ and its office is dependent on their head-quarter that is in USA and authors couldn’t get time earlier because of their busy schedule for performing SPGQM. So that, it can be possibility that people working at particular branch might not have much knowledge about their process of measurement process. However, interviewee had much knowledge of project management, SDLC processes, extracting goals from requirements and extracting business goals, measurement goals and questions from goals.

The measurement goals (reliability and maintainability) of two projects were selected initially in first interview and they were finalized in the first meeting so that potential sub-goals can be prepared before the start of goal definition meeting. The questions and OMSD implementation was planned to be in second meeting. The potential questions and relevant measure were prepared before the start of the meeting. The purpose of defining the potential goals, questions and measure was to save the time and give more time for decision making. The threat for the goals, questions and measure was that they must cover the areas and they must be finalized by the organization personnel.

In order to minimize these threats, first, a quality study assessment in systematic review is designed in section (2.2.3). These guidelines were strictly followed during the systematic review.
In order to eliminate goals extraction threat, authors of this thesis have followed the literature guidelines, so that company personnel, i.e. project manager and business analyst defined the business goals and both authors extract measurement goals from business goals due to limitation of time, but final measurement goals were validated by the project manager and business analyst, as the un-appropriate goals were rejected by the organization personnel and new goals were also defined in the meeting. Similarly, the potential questions and their relevant measures were defined on the basis of literature and case studies available. The questions and measures were finalized in the meeting and the new questions and measures were also added in the second meeting. So at the end the goals, questions and measures were finalized by the manager, business analyst and technical team lead. There was a voting for each goal, question and metrics. If manager accepts define/change an entity then one of the two remaining personnel must at least have the same opinion. The finalization of goals, questions and metrics was done by the organizational personal. The reason for defining the potential goals/question/measures was to save the time as a limited time was available by the company.

5.1.2 External validity threats
External validity is related to the generalization of the results of a particular study [48], as it is also known as generalizing [49].

5.1.2.1 Threats to external validation
One of the main external validity threats can be relation between selection and treatment [48]. There are different threats that can occur during the systematic review and industrial interviews. One of the main external validity threats is limited number of secondary studies and large number of rejected articles. There are two kinds of external validity threats related to systematic review and industrial interviews can arise in this study. External validity threat related to systematic review is the less number of secondary studies and large number of rejected studies. In order to overcome this threat, all the positive and negative finding associated with systematic review results is reported. In the same way, systematic review (from design to completing) is also reported step by step.

In the case of industry validation, few interviews has been conducted, as only two cases are examined in this study and results cannot be generalized on the basis of a few goals defined. Therefore, the authors of this thesis stated in the future work that the framework should be evaluated on different contexts so that the framework would be validated to work properly.

5.1.3 Construct validation
According to [48], this validation is related to theory and observation. According to construct validity, the consequences of the interview or experiment should be generalized to the main idea behind the interview or experiment.

One of the main construct validation threats is evaluation apprehension [48], as it means that subjects have the propensity to perform well during the evaluation. However some people are afraid of being evaluated.

In order to eliminate the evaluation apprehension threats, interviewees of company ‘A’ was ensured that his/her name and company name will not mentioned in the thesis work.

5.1.4 Conclusion validity
Conclusion validity determines that results of a particular study are reliable in the form of statistical form and conform that they can lead to correct conclusion [48]. In conclusion validity, threats are related to those problems that directly affect the reliability of consequences [48, 49]. According to [49], Conclusion validity is also known as reliability.
There are some threats related to systematic review and industrial interviews that can affect the results of particular study. In order to eliminate conclusion validity threats is to create review protocol in systematic review to remove researcher bias [14]. This review protocol (see section 2.1.2) was re-examined by one independent researcher from Blekinge Institute of Technology, Sweden, having in-depth experience in research and systematic review. The search terms and online search resources identified in review protocol and determined by conducting the pilot study at Blekinge Institute of Technology, Sweden. One of the main validity threats during systematic review is to inclusion and exclusion of studies. For example, it is possible to include irrelevant study in systematic review, and exclude relevant primary study. In order to eliminate this threat, both authors have explicitly specified study selection criteria (see section 2.1.2.5).

The questionnaire that is developed in order to use for the industrial interview were validated and remove sloppy questions and also check the layout of questions. Heterogeneity of subject is another threat to conclusion validity [48], as it means that subjects belong to different group with respect to background, education or expertise. However homogeneity means subjects belong to same group by mean of education, expertise or background. In company A, the interviewee has project management expertise, and slightly knowledge of measurement process. Therefore the subjects of our industrial interviews was neither very heterogeneous nor very homogeneous.

Both authors extract potential measurement questions from sub-goals before the ‘post meeting analysis’ in order to save time. Extraction of questions from sub-goals takes a long time and due to limitation of time both authors first extract measurement questions and then give set of questions to interviewee for the approval. So that there is no chances of any mistake as interviewee is very experience and he checked and correct if there is any mistake. So there is no validity threat in the extraction of measurement questions from sub-goals.

Finally, goal prioritization is truly done on the basis of fact i.e. cost, resources, time, value and repetition. This prioritization meeting is totally done in a systematic way and three interviewees i.e. Business Analyst, Project Manager and Team Lead did the prioritization of goals, sub-goals and questions. The product manager rate the goals on the behalf of customer the technical team lead rate the goals on the behalf of organization and business analyst rate the goals on general basis.

The framework SPGQM is based on those models and techniques which have been proved useful on the basis of systematic review results.

During the meeting, there were two authors of this thesis, two other master students at BTH, who are working on the automation and improvements of the framework. In the meeting, two students were doing moderator role. One student was recording the whole proceedings by filling the templates of goals on Google docs. One of students was making the review of all the proceedings. The recording of the meeting proceedings i.e. structured goals were available to all the participants. There is a 15 minutes break during the interview in which templates, recording and questions reviewed by all four persons. In the end all the proceedings sent to interviewee for confirmation. So there is minimum chance of any mistake from both sides because both sides i.e. company and authors complement each other.

In order to implement OMSD there was proper planning done to only utilize the maximum time for the decision making on the attributes of the measures so the OMSD implementation was divided in two parts, in each part the OMSD was applied for the OMSD, the implementation process was defined in a structured way, first of all the measures were finalized by the company personnel then factor mapping were done on the Google docs so that values and measures are visible to everyone. The factor mapping for each project was
done later on. At the end of each session the prioritization table were presented to every on with the cost of each goal and his role for prioritization (customer, organization or mixed). So implementation of OMSD was done in a systematic way in order to minimize the chances of inaccurate results.

At the end, all the data and results of case study were sent to the company for review purpose so that there is no chances of flaws in conclusion validity.
6 **EPILOGUE**

6.1 **Conclusions**

Software engineering organizations initiate measurement programs to create a corporate memory which can be used to understand, control, assess and improve their processes and products. However, most of these organizations have difficulties in deciding which measures to collect since there is no universal set of measures for all types of organizations and projects. Practices show that measurement can be more successful, if the measures are collected based on the goals of the organization or the project. A few methodologies exist to aid the software organizations. Goal Question Metric (GQM) approach is one of the most widely known and has adopted by many organizations all over the globe.

However, there is also one another constraint for the organizations: *collecting measures cost*. Therefore, software organizations also require selecting the minimum set of measures by prioritizing them based on the importance and priority of the goals of the organization. However, cost associated with measurement to help achieving those goals. This requires a holistic approach with structured goals definition and prioritization processes. *However, there was no standard way of defining the structure, quantity and syntax of goals and questions that can guide prioritization and tracking of goals.*

In our study, we proposed a framework, which is an extension of GQM approach; it aims to fulfill the above mentioned requirements for the organizations. Basically, this framework is a combination of structured goals definition, questions definition and OMSD. The goals and questions are defined according to the attributes given in the respective templates. These attributes were given identified with the help of systematic review. These attributes (of Goals and questions) are used to provide structure, traceability (with respect to measurement goals, questions and business goals) in measurement program, version control and re-usability of the goals and question.

The OMSD was implemented for two reasons. One of them was to optimize the number of measures and another was to prioritize the goals on the basis of accumulative cost, importance and measures of the goals against the benefits that can be obtained.

A case study was done to check the application of SPGQM in industry. The manual implementation of the SPGQM with large number of goals, and questions requires lot of effort. Traceability of the goals, questions and measures is time consuming and error prone. The design of SPGQM is in the form that it can be easily automated as the procedure for goals, questions definition is structured with well defined steps.

The OMSD optimization of the measures is also in a step-by-step way. So design of the application can be based on the actual flow of the SPGQM. The SPGQM not only provides the reusability of goals and questions but the measurement repository will become richer and richer as the measurement programs are implemented. So this will not only save time, effort and money but it will make the measurement process more affective as the automation of the measurement program is one the success factors identified in the systematic review. The availability of all the measurement entities and data will provide the chance of an affective analysis within the measurement program. This will help to identify the success factors for a measurement program in the organization as well as the reasons of the failure.

The prioritization of the goals is also another success factor as the most important measurement goals can be identified at the start of the measurement program and they can be handled with care and can be monitored. In this case study the prioritization is done on the
sub-goals. But the prioritization of the main goals is also possible on the basis of accumulated cost of goals. The prioritization of the questions on the basis of measures factors is also possible. It depends on the organization and project nature as the prioritization at each level will cost time and resources.

The RQ1 and RQ2 were answered with the help of systematic review in chapter 2. The analysis of the RQ1 showed the success factors and working of measurement program. This was helpful in designing the flow of the SPGQM and consideration of success factors. The RQ2 was focused on implementation of different models, frameworks, tools and standards for the working of measurement program. This helped us to use/combine the affective concepts of measurement models, tools and standards in a single model.

The RQ3 and RQ4 are answered with the help designing a model and conducting a case study to analyze its application. The RQ3 is answered with the help of structured definition of goals which are derived from the business goals. The different dimensions of the primary goals are handled with the help of defining the sub-goals by using the goal definition templates. The questions to answer the goals are also derived in the structured way by using the question definition templates. Defining the dependency between the goals and questions not only provides the traceability between the goals and questions but it also provides the re-usability of the question for more than one goal. The RQ4 is answered after the implementation of the SPGQM. The prioritization of the goals works as a success factor for the measurement program as the goals whose achievement is important can be managed with care and continuously tracked. The prioritization of the goals on the basis of cost, importance of measures provides an effective way of prioritization.

**The essence of our study is following:**

- SPGQM is a Goal oriented and structured approach for implementation in a measurement program.
- It introduces the concept of traceability of the goals, questions and metrics in a measurement program.
- It provides the traceability of measurement program with respect to business goal.
- The structured definition of the goals and question provides the support for their re-usability as usually most of the goals and questions for measurement program are repeated.
- It’s designed with the intention of automation in future.
- The OMSD is used for the optimization of the measures for structured questions.
- The prioritization of the goals can be done on the basis of accumulated cost, importance and usage of the optimized measures.
- The prioritization of the goals can be used as a success factors as it can make the chances of success of measurement program increase.

**6.2 Future work**

- The automation of the whole framework.
- Defining alternative ways to prioritize the goals.
- Identification of factors for prioritization.
• Prioritization of goals by considering the risks and their benefits along with other factors.

• Refining the templates of goals and questions.

• Refining the derivation mechanism of measurements from the business goals.

• Implementing SPGQM in different industrial settings.
7 REFERENCES


[46] A. M. Bhatti, H. M. Abdullah, C. Gencel, “To decision on selecting the minimal required set of measures from a number of possible measures,” submitted for publication.


APPENDIX A

General Questions

1. What is your name?
2. Would you like to describe your academic and professional background?
3. What is your core field of specialization?
4. Would you like to describe your current position at organization?
5. How much time you are related to this particular field? If you like to inform your experience in years?
6. How many employees working under your supervision?
7. Do you have any kind of experience of CMMI-related activities?
8. What type of activities you are currently performing in the organization?

Organization related Question

1. Would you like to provide some general information about your software organization?
2. When your organization established?
3. How many employees are currently working there?
4. How many countries containing different branches of your organization?
5. How are you targeting your customers regarding to (bespoke or market-driven) products?
6. Which SDLC being followed in your organization?
7. What are your main Organizational goals? How your organization align them and what type of activities are performed?
8. Why your organization wants to attain the higher maturity level?

Measurement Perspective Questions

1. What type of services your Organization is providing?
2. What kind of Project/Products is developed by your company? Would you like to explain it briefly?
3. What are your main business goals for any project/product development?
4. Does your organization have a special department for measurement?
5. How are you performing measurements for your project/products in the organization and which process is used?
6. How does the organization collect measures from the projects?
7. Is there any measurement training provided? How is it? Is it only for measurement department or for all departments? Which and how people are selected for it?
8. How is the co-ordination between measurement department and other departments?
9. What type of measurement data will be collected on regular basis that is required by project managers?
10. Would you to explain about? What are particular measures and their types that threaten you early in starting of a project? How?
11. What are the types of indicators that focused during project/product development? Would you like to specify the name of some leading indicators, such as cost? Any example for explanation?
12. How did software measurements widely used for management and development decisions making?
13. How do you decide which project measurements should be collected?
14. How are you software measurements used to improve your organization performance?
15. Which type of the software measurement activities are performed in the organization?
16. What are the basic software measures are collected in the organization?
17. Did your organization use any measurement tool or framework? If yes then please specify the name? And what type of results gathered from them?
18. How you characterized the involvement of different stakeholders in deciding goals and measurement?
19. What are the main problems in the software measurement process that you are practicing?
20. Do you want to eliminate these problem and wants to improve them? Any activities that is utilized to improve them? If yes then how?
21. How do you know if your organization is working towards achieving their predefined goals?
22. How you characterize are classified that these measures are better for specific project? On which basis you select them? Is all stakeholders are involved in it?
23. How is your organization analyzing the software measurements?
24. It is valuable or only wastage of time for your organization. On what basis?
25. Do you think automated software measurement tool will support your measurement process?
26. How do you provide quality based products to the customer and what is your main motivation?

Project selection and measurement

1. Would you like to briefly explain about any project/product that was developed recently?
2. Does the project follow a written organizational policy for managing the system measurement process?
3. Which goal was more critical in this project development? Which were most important goals to achieve for this project?
4. How much human resources were used in project development?
5. How much time was consumed for project?
6. What were the main goals for this project development?
7. Which were measures selected for this project?
8. Which criteria were used for selecting measures?
9. How do you know these measures were appropriate for this project?
10. How do you select measure(s) that is appearing to be inappropriate to use?
11. When measures are considered as inappropriate, does your organization still use those measures? If yes, why are they still in use?

Closing Questions

1. Are there any other questions we should ask you about measurement activity?
2. Is there anyone else (personnel) that would provide more information about measurement process?
# APPENDIX B

## Project Goal - Reliability

<table>
<thead>
<tr>
<th>Goal ID</th>
<th>Version</th>
<th>Author</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGP1</td>
<td>001</td>
<td>Muhammad Ilyas</td>
<td>Improvement in the Reliability of the system.</td>
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<thead>
<tr>
<th>Issue</th>
<th>Category</th>
<th>Stakeholders for inf. needs</th>
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<tbody>
<tr>
<td>Reliability</td>
<td>Product</td>
<td>Customer, Project manager, Development team.</td>
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</table>

<table>
<thead>
<tr>
<th>Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>The use of product at the customer side with minimum downtime. i.e. 30 sec in one week</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Relevent Entities</th>
<th>Information needs to track</th>
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</thead>
<tbody>
<tr>
<td>Test case results, Software application</td>
<td>Mean time to failure, failure time, and application downtime.</td>
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</table>

<table>
<thead>
<tr>
<th>Relevant business goals</th>
<th>Primary measurement goals</th>
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<td>BG3</td>
<td>N-A</td>
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## Sub-goal 1.1

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<th>Goal ID</th>
<th>Version</th>
<th>Author</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGP1.1</td>
<td>001</td>
<td>Muhammad Ilyas</td>
<td>Improve reliability of product in terms of likelihood of failure in a given period of use</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Issue</th>
<th>Category</th>
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</table>

<table>
<thead>
<tr>
<th>Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>To improve the reliability of product at customer side and observe failure at specific period of time</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Relevent Entities</th>
<th>Information needs to track</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test case results, customer feedback, software application</td>
<td>Mean time to failure, failure time at specific time, and application downtime.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Relevant business goals</th>
<th>Primary measurement goals</th>
</tr>
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<tbody>
<tr>
<td>BG3</td>
<td>MGP1</td>
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## Questions related to Sub-GOal 1.1

<table>
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<tr>
<th>Associated Goal ID</th>
<th>Question Identifier</th>
<th>Question Description</th>
<th>Issue</th>
<th>Entity</th>
<th>Stakeholders for inf. needs</th>
<th>Scenario</th>
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<tbody>
<tr>
<td>MPG1.1</td>
<td>MQ1.1.1</td>
<td>How many failure conditions are resolved?</td>
<td>Failure resolution</td>
<td>Software product, software test case suit, SRS</td>
<td>Team lead, development team, Quality engineer, project manager</td>
<td>To identify the types of failure that can be occur in the future.</td>
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| Dependency (Question ID) | MQ1.1.4               |

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<th>Issue</th>
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<th>Stakeholders for inf. needs</th>
<th>Scenario</th>
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<tbody>
<tr>
<td>MPG1.1</td>
<td>MQ1.1.2</td>
<td>How many faults have been corrected and what is the proportion of faults removed?</td>
<td>Correction of faults</td>
<td>Software product, software test case suit, software bug report, SRS</td>
<td>Team lead, development team, Quality engineer, project manager</td>
<td>To identify the potential faults occurs and amount of faults removed by development team.</td>
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| Dependency (Question ID) | MQ1.1.4               |
### Associated Goal ID

<table>
<thead>
<tr>
<th>Description</th>
<th>Upgrade the software to support different machine environments.</th>
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<td>Portability</td>
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<td>Product</td>
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<td>Issue</td>
<td>Support multi-operating system.</td>
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<td>Stakeholders for inf. needs</td>
<td>Customer, developer, tester.</td>
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<td>The application must support all the operating environments i.e. Window, Mac OS, Linux, Unix etc.</td>
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<td>Application must have ability to work on different Operating systems.</td>
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<td>MP1</td>
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### Questions related to Sub-Goal 1.2

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<tr>
<th>Description</th>
<th>Can user or maintainer easily install software to operational environment?</th>
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<td>Issue</td>
<td>User friendliness</td>
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<tr>
<td>Entity</td>
<td>User manuals, software application help</td>
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<td>To check if application is user friendly or not.</td>
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### Stakeholders for inf. needs
- Customer, system user
- Team lead, development team, Quality engineer, project manager

### Scenario
- To determine the fault tolerance of the particular system.

### Dependency (Question ID)
- N-A

### Associated Goal ID
- MPG1.2

### Question Identifier
- MQ1.2.3

### Question Description
- What is the fault tolerance of the system?

### Issue
- Faults tolerance

### Entity
- SRS, Software test case suite

### Stakeholders for inf. needs
- Team lead, development team, Quality engineer, project manager

### Scenario
- To check the competency level and give instruction according to their competency level.

### Dependency (Question ID)
- N-A

---

### Sub-goal 1.3

#### Goal ID
- MPG1.3

#### Version
- 001

#### Author
- Muhammad Iyas

#### Description
- Decrease software Failure of function.

#### Purpose
- Decrease Failure rate

#### Issue
- Failure of functions.

#### Category
- Product

#### Stakeholders for inf. needs
- Customer, developer, tester

#### Scenario
- To increase the time between failure and prevent the function failure of the product.

#### Relevant Entities
- Software application, Test Cases Document.

#### Information needs to track
- Failures time of each function, time between failures occur of each function.

#### Relevant business goals
- BG4

#### Primary measurement goals
- MGP1

---

### Questions related to Sub-Goal 1.3

#### Associated Goal ID
- MPG1.3

#### Version
- 001

#### Author
- Touseef Tahir

#### Question Identifier
- MQ1.3.1

#### Question Description
- What is reliability requirement?

#### Issue
- System reliability required by the customer.

#### Entity
- SRS, Software test case suite

#### Stakeholders for inf. needs
- Team lead, development team, Quality engineer, Project manager

#### Scenario
- To identify the potential faults occurs and amount of faults removed by development team.

#### Dependency (Question ID)
- MQ1.1.3

---

#### Associated Goal ID
- MPG1.3

#### Version
- 001

#### Author
- Touseef Tahir

#### Question Identifier
- MQ1.3.2

#### Question Description
- What is the rate of software failures, and how does it change over time?

#### Issue
- Randomly occurrence of faults.

#### Entity
- Software test case suite, software failure reports, software bug reports

#### Stakeholders for inf. needs
- Team lead, development team, Quality engineer, project manager

#### Scenario
- To identify the potential faults occurs and record the time of occurrence.

#### Dependency (Question ID)
- MQ1.3.1, MQ1.1.4

---

#### Associated Goal ID
- MPG1.3

#### Version
- 001

#### Author
- Touseef Tahir

#### Question Identifier
- MQ1.3.3

#### Question Description
- What is mean down time?

#### Issue
- Application down time
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<td>To identify the application downtime in one hour.</td>
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### Appendix B-II

#### Project Goal - Maintainability

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<tr>
<td>Issue</td>
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<td>Category</td>
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<td>Scenario</td>
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<td>Number of errors, types of errors,</td>
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#### Sub-goal 2.1

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<th>Version</th>
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<td>Description</td>
<td>Decrease errors that cause failure in operation.</td>
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<td>Purpose</td>
<td>Decrease the number of errors.</td>
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<tr>
<td>Issue</td>
<td>Maintainability</td>
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<td>To remove the errors that cause problem in functionality of product.</td>
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<td>Information needs to track</td>
<td>Number of errors, failure rate, mean time between failure, types of errors.</td>
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#### Questions related to Sub-Goal 2.1

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<td>Question Description</td>
<td>What kind of errors causes failure in operation?</td>
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<td>Observation of errors that cause failure.</td>
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<td>Stakeholders for inf. needs</td>
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<td>Scenario</td>
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<td>Question Description</td>
<td>What is defect finding rate?</td>
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<td>Defects found by testing team in one week.</td>
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<td>Software test case suite, software bug reports</td>
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<td>To find the errors or defects by the testing team in one week.</td>
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<td>User shall operate system without any occurrence of failure after it maintained.</td>
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<td>BG1,BG2</td>
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<th>Touseef Tahir</th>
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- **MPG2.2**
- **Version**: 001
- **Author**: Touseef Tahir

### Question Identifier
- **MQ2.2.4**

### Question Description
**How many defects have been released?**

### Issue
Total number of defects reported by customer

### Entity
Software test case suite, software failure reports, software bug reports

### Stakeholders for inf. needs
- Team lead, development team, Quality engineer, project manager

### Scenario
To check the number of defects that have been released.

### Dependency (Question ID)
- MQ2.1.2, MQ1.1.2

### Associated Goal ID
- **MPG2.2**
- **Version**: 001
- **Author**: Touseef Tahir

### Question Identifier
- **MQ2.2.5**

### Question Description
**How many customer found defects?**

### Issue
Number of defects that have been reported by customer.

### Entity

### Stakeholders for inf. needs
- Team lead, development team, Quality engineer, project manager, customer

### Scenario
To check the number of defects that have been released.

### Dependency (Question ID)
- MQ2.2.4

### Sub-goal 2.3

### Goal ID
- **MGPR2.3**
- **Version**: 001
- **Author**: Touseef Tahir

### Description
Improve Requirements Maintainability.

### Purpose
Improvement

### Issue
Maintainability

### Category
Project

### Stakeholders for inf. needs
Business analyst, Project manager, technical team lead, requirement analyst

### Scenario
Conversion of customer needs and expectations into functional and non functional requirements

### Relevant Entities
- SRS, Prototyping, customer

### Information needs to track
Functional requirements, non-functional requirements

### Relevant business goals
BG2, BG1

### Primary measurement goals
MGPR2

### Questions related to Sub-Goal 2.3

#### Associated Goal ID
- **MPG2.3**
- **Version**: 001
- **Author**: Touseef Tahir

#### Question Identifier
- **MQ2.3.1**

#### Question Description
Is the set of requirements maintainable?

#### Issue
Size

#### Entity
SRS

#### Stakeholders for inf. needs
Team lead, development team, Quality engineer, project manager

#### Scenario
To identify the possibility that the set of requirements are maintainable or not.

#### Dependency (Question ID)
N-A

#### Associated Goal ID
- **MPG2.3**
- **Version**: 001
- **Author**: Touseef Tahir

#### Question Identifier
- **MQ2.3.2**

#### Question Description
How much effort is involved in maintaining requirements?

#### Issue
Effort

#### Entity
SRS

#### Stakeholders for inf. needs
Team lead, development team, Quality engineer, project manager

#### Scenario
To calculate the effort that is required to maintain the requirements.
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<td>Documentation</td>
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### APPENDIX C

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<th>SOMS Based Tabular Paradigm Main Goal G1</th>
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<tbody>
<tr>
<td>G1</td>
<td>Improvement in the Reliability of the system</td>
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<tr>
<td>G1.1</td>
<td>Improve reliability of product in terms of likelihood of failure in a given period of use.</td>
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<tr>
<td>Q1</td>
<td>How many failure conditions are resolved?</td>
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<td>A1</td>
<td>Failure Resolution</td>
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<td>M</td>
<td>M1: number of resolved failures</td>
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<td>How many faults have been corrected? What is the proportion of faults removed?</td>
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<td>Fault Removal</td>
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<td>M3: Number of corrected faults design or coding</td>
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<td>Q3</td>
<td>What is reliability requirement?</td>
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<td>A3</td>
<td>Reliability</td>
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<tr>
<td>M</td>
<td>M5: KLOC</td>
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<td>What is current reliability?</td>
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<td>A4</td>
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<td>M</td>
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<tr>
<td>G1.2</td>
<td>Decrease the work needed to port the product to different machine environment.</td>
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<td>Can user or maintainer easily install software to operation environment?</td>
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<td>M</td>
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<td>Q9</td>
<td>What is the rate of software failures, and how does it change over time?</td>
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<td>M</td>
<td>M15: Failures per month.</td>
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OMSD Factors Mapping For Sub-goal G1.1

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SOMS Based Tabular Paradigm Main Goal G2

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Failure Resolution
- 1: Analyzability
- 0: Diagnostic function support
- 1: Failure analysis capability
- 0: Failure analysis efficiency

Current Reliability
- 1: Defect Density
- 0: # of faults
- 0: SOLC
- 0: Number of defects
- 0: Module size

Effort
- 1: Complexity
- 0: FP
- 1: LOC
- 0: path count metrics
- 0: structuredness metrics

Fault Tolerance
- 0: Concentration of faults
- 0: SOLC
- 0: Number of defects
- 0: Module size

Failure rate
- 0: Change success ratio
- 0: Number of cases which user encounters failures during operation after software was changed
- 0: Operation time during specified observation period after software is changed

Usage
- 1: Maintenance
- 1: #modules
- 4: FP
- 4: LOC

Importance
- 3: Importance
- 4: # of faults
- 2: SOLC
- 4: Number of defects
- 2: Module size

TABLE Reliability – 5
Attributes factor mapping

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Failure Resolution
- 1: Analyzability
- 0: Diagnostic function support
- 1: Failure analysis capability
- 0: Failure analysis efficiency

Current Reliability
- 1: Defect Density
- 0: # of faults
- 0: SOLC
- 0: Number of defects
- 0: Module size

Effort
- 1: Complexity
- 0: FP
- 1: LOC
- 0: path count metrics
- 0: structuredness metrics

Fault Tolerance
- 0: Concentration of faults
- 0: SOLC
- 0: Number of defects
- 0: Module size

Failure rate
- 0: Change success ratio
- 0: Number of cases which user encounters failures during operation after software was changed
- 0: Operation time during specified observation period after software is changed

Usage
- 1: Maintenance
- 1: #modules
- 4: FP
- 4: LOC

Importance
- 3: Importance
- 4: # of faults
- 2: SOLC
- 4: Number of defects
- 2: Module size

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## TABLE Maintainability – 2
### OMSD Factors Mapping for G1.1

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### OMSD Factors Mapping For Sub-goal G1.2

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<th>R</th>
<th>R cost</th>
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<th>Effort</th>
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## TABLE Maintainability – 4
### OMSD Factors Mapping For Sub-goal G1.3

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<th>Measures</th>
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<th>Duration</th>
<th>CCTW</th>
<th>UMMR</th>
<th>MMR</th>
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### Table 4.11: Goal and Sub-goal prioritization

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<th>Organizational side value</th>
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