Deciding on Optimum Set of Measures in Software Organizations

The Optimum Measures Set Decision (OMSD) Model

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ABSTRACT

Software measurement process is a significant part of process improvement in software organizations. The organizations usually follow a measurement process that includes measures selection, data collection, and analysis to improve their processes. Most of the software organizations face difficulties in deciding the measures to collect since there is no universal set of measures for all types of organizations and projects. Experience shows that measurement can be more successful if the measures are collected based on the goals of the organization or the project which it will serve. A few methodologies exist to aid the software organizations. Goal Question Metric (GQM) is one of the most widely known and used one. However, one of the major constraints for the organizations is the associated cost when collecting the measures. Therefore, software organizations also require selecting the optimum set of measures which are good enough for the organization.

This thesis study aims to provide solution for this problem. We propose a model, named ‘Optimum Measure Set Decision Model (OMSD)’, which is an extension of GQM paradigm. The model is based on a heuristics approach, which aims to provide the optimum set of measures from a large number of possible measures. To develop the model, we identified the factors which are significant in selecting the optimum set of measures based on the literature survey results. Then, we evaluated those factors by conducting an empirical study.

As the empirical research strategy, we used traditional fixed non-experimental design strategy. We performed a survey by distributing a structured questionnaire in order to evaluate the important factors we identified when selecting the optimum number of measures to be collected in an organization. We evaluated the heuristics rules by means of some sample cases we created. Moreover, we provided an idea for an alternative solution to optimize the number of measures to be collected for the future research.

**Keywords:** Software Measures, Software Process Improvement, GQM, GQIM
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ABBREVIATIONS AND DEFINITIONS

The important technical terms are defined here and details are given in the literature review section (chapter 2).

- **Software Metrics Program** – A program that focuses on collecting data on metrics, analyzing and drafting conclusion for the purpose of improving software processes.
- **ISO/IEC 15504** – A standard for software process improvement.
- **CMM (Capability Maturity Model) / CMMI (Capability Maturity Model Integration)** – CMMI is another standard for process improvement and furthermore, CMMI is made based on CMM and ISO/IEC 15504.
- **GQM** – Goal Question Metric (GQM) is a systematic approach for deciding on measures in relation with the goals that helps achieving these goals.
- **M2P and MPSP** – These are the frameworks made for assessing the effectiveness of measurement program.
- **Classification Tree Analysis** – A technique based on tree structure used for selecting optimal set of metrics.
- **Multiple Metrics Graph** – Another technique used for optimizing metrics selection.
- **GQIM** – It is an approach different from GQM as it uses the term ‘measures’ in place of metrics and user defines indicators and measures based on the needs to manage goals and make decisions.
- **Standards Driven Metrics** – It is a way to select metrics that are according to standards and applied successfully in different projects and organizations.
- **Decision Maker Model** – Another method consistent with the GQM method, with a focus on decisions making according to needs of decision maker.
1 CHAPTER 1 – INTRODUCTION

This chapter aims to introduce the thesis in terms of thesis purpose, overview of the thesis and thesis structure.

1.1 Purpose of the Thesis

Software measurement programs in software organizations are reported to fail because of different factors [23, 46, 47, and 48] that hinder measurement programs execution. These factors include improper goals definition, wrong cost and time estimate of measurement process, inexperience measurement resources and difference of action plans from organization processes. The proposed approach aims to reduce the impact of these factors by considering cost and time as important for data collection on measures. Along with that, focus on measures selection (using defined criteria and decision making rules) in accordance with the goals helps meeting organization business objectives at the end.

Most of the software organizations face difficulties in deciding the measures to collect since there is no universal set of measures for all types of organizations and projects. Experience has shown that measurement can be more successful if measures are collected based on the goals of the organization or the project which it will serve. A few methodologies exist to aid the software organizations to decide which measures to collect, such as Goal Question Metric (GQM) [13], Decision Maker Model [49], Standards Driven Metrics [49], and Goal Question Indicator Measure (GQIM) [42].

On the other hand, major constraints for the organizations are the associated cost and time when collecting the measures. Therefore, software organizations require minimizing the number of measures to be collected while collecting the ones which are good enough for them. This requires an optimization approach in this process.

In this study, we aim to identify the factors which play an important role in this optimization process. We propose a model to aid the organizations for this process which is an extension of GQM paradigm. The model is based on a heuristics approach, which aims to provide the optimum set of measures from a large number of possible measures. Cost and time factors play a key role in data collection on measures along with other factors such as value (importance), type and repetition. Cost, time and importance factors are used in the decision making about optimum set of measures. Moreover, an Alternative approach is also proposed to find the optimum set of measures for measurement process.

1.2 Overview of the Thesis

The research work starts by an extensive literature review on the work done previously in the field of software measurement. We also reviewed optimization and decision making in the context of software measurement processes. The literature study includes focus on Measurement Programs, Software Process Improvements, Standards used for measurement, Software Measurement Frameworks, Measurement Methodologies and Optimization Techniques (explained in chapter 2).

The literature study revealed that no significant work is available on guiding managers in selecting the optimum number of measures. In this thesis study, we propose an approach, Optimum Measure Set Decision (OMSD) Model, which will enable software organizations to decide on an optimum number of measures. The proposed model extends a well-known framework called Goal Question Metric (GQM). Basically, GQM helps organization to collect measures based on the goals of organization or the project which it will serve. The model proposed in this thesis study
aims to minimize number of these measures based on the factors identified which are important in decision making. There are mainly 5 steps in the model (explained in chapter 3). These steps help providing a structured approach in meeting the goal of finding optimum set of measures from a set of possible measures. Factors identification is a key part of the model and plays a vital role in data collection and decision making of measures. These factors are assessed using an industrial survey. On the basis of factors such as time and cost, decision on what measures to select is made. This model is based on the heuristic approach (explained in chapter 3) that involves much human interaction. The identification of selection criteria (used in step 3 of OMSD model), factors definition, decision making rules and a systematic approach towards optimum measures selection are the main contributions of OMSD approach that will guide managers deciding on right number of appropriate measures. Effective decision making will also give rise to process improvement and maturity.

There is a limitation of much human interaction in the OMSD model approach. Optimization techniques studied in the literature helped proposing an Alternative approach to OMSD model that will reduce human interaction and automate this measures selection process.

In a nutshell, the proposed approaches in this thesis study guide managers for optimum measures selection in the software measurement process leading towards process improvement and maturity.

### 1.3 Thesis Structure
The thesis report contains 6 chapters and the Figure 1.1 below gives a visual representation of the thesis.

### 1.4 Research Questions
The research aims to answer the following questions:
- What are the different techniques used for selecting optimum measures set in software measurement process?
- What are the different optimization techniques that can be utilized for decision making in software measurement process?
- What are the different standards/frameworks/models available which facilitates in software measurement process?
- What are the main challenges faced by organization while implementing measurement programs and how these challenges can be solved?
- What are the main factors that play crucial role for measures selection in software measurement process?

### 1.5 Research Methodology
A mixed method research approach [1] was used for this study that includes qualitative and quantitative analysis. A qualitative analysis was carried out in order to investigate the state of art research available. The qualitative analysis includes a literature review on two major topics.

- The first one is a review of the literature on ‘Software Measurement’ that helps in understanding the number of factors affecting measures selection and available measurement frameworks.
- The second one is a review on ‘Software Process Improvement’ that provides an understanding of the role of measurement in process improvements.
The literature study results in the identification of key factors that play crucial role in measurement process and also suggestions for the improvements. On the basis of facts revealed during literature survey, a model was proposed (OMSD Model). This model is an extension of a famous measurement approach known as GQM paradigm [13]. Some heuristics rules are also included in the model in order to facilitate the decision making regarding measures selection. Factors identified during literature study constitute the core part of the OMSD model.

The quantitative analysis involves:

- Survey
- Sample Case

Main aim of the survey is to evaluate the identified factors. Survey was carried out in the form of a structured questionnaire which facilitate in determining the industrial importance of core part of the model (i.e. the identified factors which affect decision making for the measures to be collected). Survey results also reveal some major challenges that organizations face while performing measurement. Heuristics rules of the model are experimented by means of a sample case we built for a thorough execution of the model (see Chapter 5). Main aim of the sample case development is to assess the applicability of our approach in a measurement process. Data utilized in sample case was taken from ISO 25000 standard. Figurative representation of the whole approach is given below in Figure 1.2.
Figure 1.1: Thesis Structure - Visual Representation of the Thesis
 protecting the natural environment and ensuring the sustainability of the ecosystem. This is crucial for the long-term survival of species and the health of the Earth.
2 CHAPTER 2 – BACKGROUND AND LITERATURE REVIEW

This chapter explains the background of this thesis work and the related literature review.

2.1 Background

Measurement is a fundamental process in all engineering disciplines. In software engineering, a number of different measures are used to collect data. These include measures such as design measures, code measures, and process measures [3].

Software measurement is the process for collecting, analyzing and communicating measures of software processes, products and services [4]. Software measurement has become an integral part for software development process due to its significance in project estimations, decision making and software process improvement. Software measurement processes support organizations to achieve technical and business objectives. Predefined roadmaps for the measurement process are identified and explained by the expert teams to make sure the process carries on properly. There are different factors such as cost and quality that are important in conducting a software measurement process. Different measurement theories [5] are also proposed and validated to see the significance of measurement in software development.

Software measurement process also involves data management that includes data gathering, data analysis and interpretation on that data. The data is also used in making repositories (also referred to as factory) that contains experiences from the previous projects. Experience Factory (EF) [6] is a process implemented for analyzing software experiences that leads to appropriate project planning and continuous improvement of the organization’s software process. This process supports reuse of experience and collective learning by understanding, assessing and packaging of the data [7].

Measurement is one of the key processes in decision making that leads to the software process improvement [9]. Appropriate measurement process faces challenges of measurement data collection and analysis that shows the importance of controlled and systematic measurement process.

Various frameworks and models have been developed for making measurement process systematic so that software organizations get the required information. These frameworks focus on the critical factors of software process including quality [10], cost and performance [11]. Goal Question Metric (GQM) [13] paradigm is one of the well-known frameworks used in deriving measures from organization or business goals [12]. There are frameworks that focus on the software attributes like quality, performance etc. Software Quality Measures Framework [22] is based on the GQM approach that quantitatively assesses quality of software (assess quality in terms of quantity). There are other types of frameworks for assessing the effectiveness of software measurement process such as M2P [23] and MPSP [24]. These frameworks reject the notion of fixed set of measures. Instead, they offer a method to assist tailoring sets of measures to specific organizational goals and environments. This problem is studied and it is objective of this thesis work to provide a way for selection of a minimized set of required measures from a set of possible measures while having cost, effort and time constraints of a project in mind.

Faced with a high number of measures to be collected for software process improvement reasons, most organizations want to know whether all those measures are
equally important or some are more important than the others. The selection of minimum required measures is therefore required by the software organizations. There are different techniques available for this purpose and their efficient selection in a measurement process depicts manager’s self-efficacy and expertise.

Though there have been many models and frameworks proposed for different measurement processes, they usually focus on “what” measures to collect based on the organizations’ goals. However, minimizing the number of measures is necessary for the organizations to reduce the cost of collecting those measures.

2.2 Literature Review

2.2.1 Software Measurement Program

Measurement programs have become an essential part of any software development process. Like other software processes, the measurement process activities are carried out smoothly by the definition of a program named measurement program.

2.2.1.1 What is a Measurement Program?

Measurement program can be defined as “a program of identifying and collecting measures that lead to data analysis and getting required results for meeting the defined goals”.

Software measures help sorting out the good from the bad and ugly [14] and the programs used for applying these software measures are measurement programs. The strategy of an organization has a direct impact on its software processes i.e. development, measurement and testing processes. Grady and Caswell [19] suggested that the measurement program should be a part of an overall strategy for software development process improvement. Measurement programs should be designed and implemented in accordance with the organizational strategy to get the most benefit from it. The data is collected by a set of techniques and methods that undergoes through analysis and interpretation. These interpretations are then used to see if the required goals are met or not. The measurement programs are a directed way to analyze the overall project execution effectiveness.

2.2.1.2 Why it is Important?

Measurement programs are essence of any organization’s improvement plan. Measurement programs ensure the smooth execution of improvement process and confer broader benefits. Organizations plan about improving their software processes and measurement data helps identifying which phase require improvement. The data is saved in a database to be used periodically in future.

Measurement provides an insight to the development and enhancement process of the organizations [20]. Measurement programs include several steps starting from identifying measures, collecting data, analysis and drafting results from it. It is also said that:

“The benefit and value of software measurement comes from the decisions and actions taken in response to analysis of the data, not from the collection of the data” [21].

The analysis of data helps drafting results that are used for decision making and leads towards the goal accomplishment i.e. process improvement. Results from each project have an impact on the selection for measures for the next project in order to achieve continuous improvement. The effective results of measurement programs have
The importance of measurement program for a successful project cannot be denied. The way how the measurement program is implemented shows effectiveness of the whole software process.

Steven R. Rakitin [17] quoted 10 steps approach for implementing the software measurement program originally identified by Grady and Creswell [19] as:

- **Define the objectives of the software measurement program** – Every organization and the projects going on under that organization have a set of objectives. There is a need to identify and map those objectives to the measurement program objectives to achieve the overall project goals.
- **Assign responsibility** – The resources are assigned responsibilities based on their capabilities.
- **Do research** – A research is carried out to see the different prospects of applying a measurement program including its benefits with respect to the cost involved in the process.
- **Define initial measures to collect** – Once research is conducted, initial set of measures are defined that give start to data collection phase of measurement program.
- **Sell the initial collection of these measures** – Selling the collected measures data involves looking into the benefits of this process and convincing the higher management to follow the program appropriately.
- **Get tools for automatic data collection and analysis** – Automation is needed for better time utilization i.e. doing more work in less time. Tools are used for collecting measures data and analyzing it automatically in order to save resources time.
- **Establish training in software metrics** – When the program undergoes, training about measurement is required to give knowledge to the resources about the program.
- **Publicize success stories** – It is important to share the benefits of measurements in order to highlight the importance of a measurement program for a software project.
- **Create a measures database** – The results of a measurement program are then saved and measures repository is maintained to ensure that this data and results can be used as a baseline for the upcoming projects.
- **Improvement of the process in an orderly way** – Improvements are always good for a software measurement process. The data and results from measures
database are used to improve the measurement process in a systematic way for the next use.

This 10 step approach by Grady and Caswell is a generic approach that different organizations have adopted and modified according to their requirement. Examples of Hewlett Packard (HP) and Motorola are given below.

Robert B. Grady [14] described the program developed in Hewlett Packard (HP) as:

- **Making council** – A group is made that deals with the measurements decisions and documentations involved in the whole measurement program.
- **Starting with small primitives for measures** – This is the same step as written in the previous 10 step approach. Here, initial primitive measures are collected first that leads to further measures data collection and analysis.
- **Training of functional managers** – Providing knowledge about measurement is an important consideration and should be taken care of properly.
- **Job of productivity managers is defined** – HP define the jobs of individuals well to get the output accordingly. The data about effectiveness of the process is collected from the accounts apartment and productivity department.
- **Two-day software measurement class** – A two-day measurement lecture is carried out in HP to give basic knowledge of software measurement and effectiveness of measurement programs.
- **Good tools support is provided** – Measurement team is also supported with a tool kit [18] that helps them performing measurement process accurately. The tool support is used for data collection, analysis and interpretation.

The measurement program of Motorola also resembles to some extent with HP’s measurement program as Michael K. Daskalantonakis [19] describe it:

- **Setting quantitative goals** – Measurement is all about handling data that is a quantitative way for achieving goals. The measures are selected in accordance with the goals and measurement program is carried to achieve these goals.
- **Establishing Metrics Working Group (MWG)** – Like in HP, here a group named MWG is established that consists of technical staff and management individuals having the knowledge of measurement that work during the measurement process.
- **Using measures for improvement over time** – The use of measures is important for improvement and this fact is well understood in Motorola. They are using measures to collect data in order to see the current state of process and process improvement.
- **Using measures from in-process control** – The measures are also used to gain the in-process control and to see that the process is going in the right direction. The results of the measures data collection phase show your present state and the way you differ from the designed roadmap.
- **Metrics User Group (MUG) establishment in addition to MWG** – Another group MUG is established along with MWG in Motorola. The responsibilities of this group differ from the MUG in the respect that they are more concerned with the user oriented data whereas the other group focus on the overall measurement program.
Starting with baseline and using it to evolve the measurement program – Like in HP and the 10 steps approach of measurement program establishment, a baseline for measurement program is made and the results from this baseline are used for evolving the program.

Reusing experiences of measurement program from previous projects – Results from the measurement programs are saved and reused to provide guidance in selecting appropriate measures for the next projects.

### 2.2.1.4 Why Measurement Programs Fail?

Software measurement programs are reported to be a failure in many organizations and there are different factors causing this failure of software measurement program as discussed in literature [46, 47, 48, and 23]. These factors include:

- Focusing on collecting process rather than having clear action plan according to organization process.
- Inadequate data collection and wrong interpretations of data that leads to ineffective decision making.
- Cost not planned according to the organization’s budget.
- Improper time estimates causing time overrun.
- Inadequate training, team inexperience, lack of enforcement from management.
- Improper goal definition – too abstract goals.
- Inappropriate measures selection – not in accordance with measurement goals and resources experience.
- Focus on measurement data collection in place of application of decisions.

These factors cause failures in software measurement programs and our approach (explained in chapter 3) have attempted reducing impact of these factors. Short overview of solutions to these issues is explained as:

- Effective actions plans are important in success of any measurement process. We have used GQM [13] and GQIM [42] (built on Goal-Driven Measurement Approach [21]) as a base in constructing the OMSD model. The selection of optimum set of measures in accordance with the goals leads to effective action planning.
- We have defined a set of factors (defined from Literature study and verified in industrial environment) to collect only relevant data on the measures. The use of decision making rules (explained in chapter 3) in accordance with the organization’s limitation and constraints in terms of time and cost reduce this factor.
- Cost and Time factors are used in the model for data collection and realistic estimation is advised on these factors in order to avoid cost and time overrun in the projects.
- The implementation of measurement programs (explained in previous section) includes measurement training of the resources that can be useful during the measurement process execution. Also definition of goals by involvement of management ensures that the measurement process will be implemented completely and selected measures will be used to attain goals.
- Inappropriate goals definition can lead measurement program to a wrong direction. The goals are defined by measurement experts in coordination of senior management so that the goals should not be too abstract or too detailed. This way of goal definition reduces risk of mismatching organizations objectives with the defined goals.
- It is important to select the right measures to avoid failures later on. Our approach has defined initial measures selection criteria (explained in section 3.3,
step 3 of OMSD model) using ISO standards and CMMI. Once the goals are defined, the risk of inappropriate measures selection is significantly reduced using this criteria.

- The thesis work focuses on providing an effective approach for decision making so that results of the measurement data can be applied that leads to process improvement. As the decision making rules are defined keeping organizations preference in mind, it is purposeful and easier to implement the results.

2.2.2 Software Measurement for Software Process Improvement

There are many measures described in software engineering literature [25]. These measures are used for different situations in different projects. Measures play an important role in understanding, controlling and improving software processes. Right measure selection is a challenging task because selecting more than required measures could increase cost as well as lay burden on resources regarding its maintenance. Tom De Marco said [8]:

“Metrics are good, more would be better and most is best but the importance of cost and time factor cannot be denied. Faced with a high number of measures to be collected for software process improvement reasons, most organizations want to know whether all those measures are equally important or some are more important than the others.”

The only way to evaluate the purpose and utility of each measure is to first determine the needs and goals of development organization. In this way, required data could be collected and measures analysis could be performed keeping in view the main goal of understanding and improvement. Many maturity frameworks/standards/models such as CMMI [26, 29] and ISO 15504 [27] consider that measurement plays a key role in software process assessment and improvement [28].

Collection of measures in an organization is tied to the maturity of its development process [30]. Pfleeger and McGowan [30] discussed that a project can only measure what is visible and appropriate. A project with unknown and ambiguous requirements should start measurement process by measuring effort and time in order to reduce risks of over cost and time. In this way, a base can be established in order to monitor the progress of improvements activities. When requirements are well-known i.e. defined and structured, general productivity measures are established through project management measures. Product measurements are added into the project when process is well defined. In this way, characteristics of intermediate products can be identified and used to get an idea about quality of the complete product. Process measures are added when the project is mature enough (has a central point of control) with feedback to the responsible person. These feedbacks facilitate in deciding on how to proceed further when a critical situation occurs in the project. Mature projects include process measures and feedbacks which facilitates in dynamically changing the process as the development progresses. Process maturity frameworks identify that measures are useful not only for process monitoring but also for process improvements. Measures facilitate management in [30]:

- Providing a deep insight into process and its resultant product.
- Effectively controlling process as well as product.

In literature [30], a division of measures with respect to maturity level of organization is presented. Additional measures are collected and analyzed when the process improves. Table 2.1 shows the maturity levels and their related measures.
Table 2.1: Process Maturity Levels Related to Measures [30]

<table>
<thead>
<tr>
<th>Level</th>
<th>Characteristics</th>
<th>Measures to Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Optimizing</td>
<td>Improvement feedback to process</td>
<td>Process + feedback for changing process</td>
</tr>
<tr>
<td>4. Managed</td>
<td>Measured process (quantitative)</td>
<td>Process + feedback for control</td>
</tr>
<tr>
<td>3. Defined</td>
<td>Process defined, institutionalized</td>
<td>Product</td>
</tr>
<tr>
<td>2. Repeatable</td>
<td>Process dependent on individuals</td>
<td>Project</td>
</tr>
<tr>
<td>1. Initial</td>
<td>Ad hoc</td>
<td>Baseline</td>
</tr>
</tbody>
</table>

2.2.3 Software Measurement Frameworks

Over the years, the theories about software measurement have been matured and a lot of frameworks for applying software measurements are proposed. The following subsections entail some of the frameworks for software measurement like GQM [13], Software Quality Measures Framework [22], M2P [23], MPSP [24], GQIM [42] and Measurement Information Model [44].

2.2.3.1 Goal Question Metric (GQM)

Software measurement is about finding attributes and entities that we want to measure. Goal Question Metric (GQM) [13] is an approach that helps finding those attributes by applying measures. GQM approach has 3 main steps including Goals identification, questions derivation and measures selection. The approach is based on the Goal-Driven Software Measurement [21]. There is an approach given by Grady and Caswell [19] briefly described in section 2.2.1.3. Goal-Driven software measurement identifies 10 steps in 3 set of activities to establish a measurement program aligned with the organization’s business processes.

The 10 steps are classified into 3 categories [21] as follows:

- **Identify Goals**
  - **Identify the business goals** – The first step in identification of measurement goals is to identify business goals so that they can be mapped on the measurement goals. There is a risk that measurement goals may not be aligned with the important issues in the organization if they are made without looking at the strategic goals of the organization.
  - **Identify what you want to know or learn** – This step is based on the business goals identification and here you identify and document what you want to learn and know about entities with respect to the previously defined goals.
  - **Identify your sub-goals** – The subdivision of goals is necessary for refinement of the goals and helps identifying the entities.
  - **Identify the entities and attributes related to your sub-goals** – Once the goals are divided and sub-goals are identified, attributes and entities related to the work processes are identified.
  - **Formalize your measurement goals** – The last step of first category is to formalize the measurement goals. The need is to derive formal, well-structured measurement goals that are synchronized with the organizational strategy goals.

- **Defining Indicators**
  - **Identify questions and the related indicators** – The second step of Goal-Question-Metric approach is to draw a set of questions that are linked to
the goals. The answers to these questions will help achieving the measurement goals.

- **Identify the data elements** - The data elements are reflected by the indicators and questions. Once the questions are finalized, data elements are identified that help answering the questions.

- **Define the measures** - after the questions definition, it is required to define measures that will be collected for achieving the goals.

**Creating an Action Plan**

- **Identify the actions** – A plan about the set of actions taken to implement the measures is made. The possible actions could be what data should be collected, identifying the sequence of activities and identification of the needed resources for data collection.

- **Prepare a plan** – The plan is prepared when the set of actions are identified. The plan constitutes documenting sequence of tasks and actions in order to achieve process improvement. There is a need to stay focused for correctly implementing the measures.

GQM uses these 3 categories for defining its 3-step process. The 3 steps are identification of goals, drafting questions related to the goals and then deciding on the measures. This approach focuses on guiding the measures program to know what should be measured rather measuring what is convenient to measure [13]. As there is no universal set of measures that applies to all projects, there is a need to filter out the required measures from a pool of available measures. This is important for achieving organization wide goals and objectives. The measurement program can be more successful if it is designed with the goals of the project in mind.

Projects goals definition is related to the business and product needs of an organization. Identification of major goals of the project should be done in coordination with the business strategy in order to accomplish the ultimate business goals of an organization. Once the goals are identified, these are divided to form sub-goals. It is done to make the question derivation process easier. The questions should be defined in relation to the sub-goals. Once the questions are listed, the measures should be selected. One goal can lead to more than one questions and a single question can results in multiple measures collection. The less the measures are, the more focused you will be. At the end, these measures are collected and analyzed showing if the goals are met or not.

### 2.2.3.2 Goal Question Indicator Measure (GQIM)

Another approach closely related to GQM is developed by Park et al named as Goal, Questions, Indicators, Measures (GQIM) [42]. Like the GQM, it helps organization to map their development measurement to business objectives. But this approach differs from GQM in a way that it uses the term measures in place of metrics due to absence of meaning of this term in the industry. The GQIM approach involves the following ten steps [42]:

- **Identify business goals.** The first step of GQIM is to identify company’s business needs and requirements that will be considered during the measurement process.

- **Identify what you want to know or learn.** It is very important to know that what is aimed to learn. This is related to the goals in an organization. The learning objectives are intended to provide improvements in resources skills and process maturity.

- **Identify sub-goals.** Once the goals are defined, sub-goals are identified and these sub-goals are grouped within a single goal. These groupings are made in group discussions with mutual agreement of all the group members.
Identify entities and attributes related to sub-goals. The next step is to identify attributes and entities that will help meeting the goals.

Formalize measurement goals. Once you know the attributes that you have to collect, it is important to know the goals of measurement process. Purpose, perspective and environment of each sub-goal are identified.

Identify quantifiable questions and the related indicators. Questions and indicators are identified like in GQM approach that helps achieving measurement goals.

Identify data elements. Data elements and data collection procedures are identified in this step that will be collected to construct indicators.

Define the measures. After the data elements are known and documented, measures are defined that will be collected to answer attributes and meet goals.

Identify the actions. Activities are defined that will be carried out to implement the measures.

Prepare a plan. Plan containing all the actions and their appropriate description (goals, scope etc) is prepared that guides the measures implementation process.

2.2.3.3 Software Quality Measures Framework

Quality is an important attribute for a product and there are many tools and techniques used for achieving better quality results. The quality concerns include product as well as the process quality. It is difficult to measure quality quantitatively due to its nature of being a relative measure [22]. Quality is always measured in relation to some other attributes. As quality of a program ‘A’ is measured quantitatively in comparison with quality of program ‘B’. This comparison give base for analyzing which program has better quality. The more precise definition of software quality will lead to quantitative measure of software quality for objective analysis [22]. This framework is based on these factors that lead to criteria definition and associated measures collection.

This framework is also based on 3 steps as in GQM paradigm. The steps are:

- Factors identification – major aspects of software quality
- Criteria definition
- Measures selection based on the defined criteria

Factors are the major quality concerns of the software. Identification of factors involves consideration of the user perspective about quality. Everyone who uses the system, are users of the system including program manager, customer and developers. The user needs a set of factors when checking the quality of the system. The software quality factors include correctness, reliability, efficiency, integrity, usability, maintainability, testability, flexibility, portability, reusability and interoperability [22]. Once the factors are listed, a set of criteria is established for each of the factors that lead to the measures selection to fulfill these criteria. This is how that software quality measures evaluate the software attributes i.e. quality in this case.

This framework involves quantitative measure of the quality, not only concerning the code of the product but also documentations associated with the product. This depends on the criteria of checking factors. Measures collection results tell the quality standard of any product. This framework is important as it helps managers to identify what qualities are significant for a product or process. It is helpful in assessing quantitatively that how well the project is progressing in relation to the established goals. This framework is beneficial in measuring quality when applied in early stages of the development to prevent loss in later stages. It can also be used for measuring other software attributes i.e. performance, security etc after slight modifications.
2.2.3.4 Meta-Measurement (M2P) and Measurement Program Survey Project (MPSP)

There are other types of frameworks developed for assessing the effectiveness of measurement process such as Meta-measurement (M2P) framework [23] and Measurement Program Survey Project (MPSP) framework [24]. M2P used the best practices of measurement and assess the measurement programs by applying it on a MOSMAN [23] project. This MOSMAN project demonstrated how to identify opportunities to improve both the software measurement process and the target process by the use of specific instruments. Similar to the M2P framework, MPSP also produced a validated instrument for data collection about measurement programs.

2.2.3.5 Measurement Information Model

There is another model proposed for making measurement process easy named Measurement Information Model [40]. This model helps in identifying attributes that should be collected in a measurement process in order to satisfy the information needs. This model describes how attributes should be quantified and converted to indicators that make decision making process easier. The indicators are then interpreted to information product that is our information needs, required in decision making process. Efficient decision making process requires effective information. The model includes certain concepts [40] that are explained hereafter.

- **Entity** – is an object that is characterized by its attributes. Typical software objects are classified as products, process and resources. Product attributes includes code, documentations, test data etc. Process attributes are related to the software process and includes processes such as design process, coding process etc whereas, resources attributes include coders and testers etc.
- **Attribute** – is characteristic of an entity that can be distinguished quantitatively or qualitatively by human or automated ways.
- **Measurable Concept** – is an idea about the entities that should be measured to satisfy information needs of the measurement process.

The model defines three types of measures i.e. base measures, derived measures, and indicators [40].

- **Base Measure** – is a measure defined in terms of an attribute and it is a way for calculating the attribute. It involves certain measurement methods and scales used to map the results appropriately.
- **Derived Measure** – is a measure that is defined in terms of two or more base measures. Due to this combination, it covers more than one attribute or same attribute for multiple entities.
- **Indicator** – is a measure that estimates the attributes with respect to the defined information needs. As it is on the upper level of the model, it relates to the required information.

It starts from required information. We know the information needs of our decision process and we get base and derived measures of our process. These measures in turn help in collecting data on the attribute. Data collected on the attributes is related to what we have required in the start. Moreover, the effective data from here guides in making appropriate decisions in the measurement process.

The study of above described frameworks shows that the focus is on finding measures by focusing on the goals. But there has not been any model/framework that goes one step ahead and helps organization in selecting the required set of minimal measures out
of the available pool of measures. The research work in this report will help developing a model for solving this issue (discussed in chapter 3).

2.2.4 The Techniques Proposed for Deciding Measures

This section briefly describes the available tools and techniques which could facilitate us in our study. Main purpose of these tools and techniques is to facilitate software organizations in the selection of optimum set of measures in order to make efficient use of their scarce resources. Currently there is no particular tool/technique available which can do this job by itself. Experts of measurement use a combination of these tools to accomplish this task.

In order to support measures collection and analysis, software development projects are provided with a software development toolkit [17]. This toolkit is tailored according to the requirements of each individual project. It contains different tools which facilitate in measures collection and analysis. Following sub-sections describe briefly about some techniques related to our study.

2.2.4.1 Classification Tree Analysis

Classification Tree Analysis approach is helpful in determining best predictor measures sets for a particular situation. By performing this analysis approach we can generate a decision tree which facilitate in identifying the measurements that predict target values effectively.

Consider a large collection of measurements are collected for each project in a collection of different projects. These measurements include both typical measures (e.g. lines of code, complexity, no of defects etc) as well as process characteristics descriptions (e.g. Prototyping usage for requirements, amount of reuse, defect density model usage for testing etc) [30]. The target characteristic for this particular case is the quality. Quality is measured through the following formula [30]:

\[
\text{Number of Errors} \quad \frac{\text{1000 Lines of Code}}{
\]

Scale used for measuring the quality is [30]:

Software is of poor quality if: \( \text{Errors} > \frac{5}{1000} \text{ LOC} \)

Classification Tree Analysis approach is applied on the above scenario in order to identify the measurements which are best predictors of poor quality [30]. Classification Tree Analysis results in the generation of a decision tree shown in Figure 2.1 below.

A circle with a minus sign in it indicates ‘High Quality’ which means five or less than five errors per thousand lines of code. Plus sign inside the circle depicts ‘Low Quality’ means more than five errors per thousand lines of code [30].

Decision tree analysis approach results in determination of the following measures [30]:

- Size of module in LOC
- Cyclomatic Complexity (CC)
- Number of changes
- Subjection to a design review
According to decision tree, above mentioned measures are the best indicators of poor quality predictions. From above example low quality is expected when “module length is between 100 and 300 lines of code and complexity of module is 15 greater” or “module has changed at least five times and its design is not reviewed” [30].

Main advantage of Classification Tree Analysis technique is that it conveys additional information by viewing measures compositely while keeping their individual identities.

Main advantage of Classification Tree Analysis technique is that it conveys additional information by viewing measures compositely while keeping their individual identities.

![Figure 2.1: Classification Tree adapted from [30]](image)

2.2.4.2 Multiple Metrics Graph

Multiple Metrics Graphs technique is used to depict combination of measures. It was suggested by Pfleeger et al [31]. This technique is basically a variation of another technique called Kiviat diagram or graph developed by Morris and Roth in 1982 [31]. Kiviat diagram consists of a circular pie and it is used to depict the characteristics reported in simulations. Pie is divided into equal slices and each slice displays a characteristics or measurement as shown in Figure 2.2 below.

Outer circle represents the maximum and inner circle represents the minimum. In order to indicate the overall performance a point is placed on the line for each measure with respect to its progress towards goal. At the end, these points are connected which results in a polygon shape. This polygon depicts the overall performance. Pie is divided into unequal slice in case of Multiple Metrics Graphs. The size of each slice shows importance of its respective measure. Inner circle depicts the goal for each measure. A point is placed inside slice with respect to its progress towards goal completion. Lines are drawn from each point towards the intersection of goal line. If the resulting point is inside the inner circle then progress is satisfactory otherwise some respective actions should be taken in order to improve progress. Outer edge of pie represents the worst case where as its center represents the best case [30].
A multiple metrics graph is shown in Figure 2.3 below.

In Multiple Metrics Graph, the performance (both overall performance and performance with respect to individual characteristics) can be monitored by tracking the area of polygon in order check whether it is improving or not.

2.3 Summary and Analysis of Literature Review

Our main aim to make this literature analysis was to identify the work related to the topic “Deciding on the optimum set of measures in software organizations”.
Keyword used included decision making regarding measures selection, collection, prioritization, optimization etc. In order to achieve this goal, first we have to create a sound understanding regarding basic concepts of measurement process, factors related to it, frameworks and methods available, tools and techniques which could help in our work.

Literature review results revealed that currently there are no techniques available to cope with the challenge of “Deciding on the optimum set of measures”. Although, it reveals some very useful techniques suggested in past (See section 2.2.4) which are very much related to our work but still a model/technique/method is required which help organizations in selecting optimum measures set.
CHAPTER 3 – OPTIMUM MEASURES SET DECISION (OMSD) MODEL

In the scope of this thesis study, we proposed a model, called Optimum Measures Set Decision (OMSD) Model. The model is based on a Heuristics approach [50], which aims to provide the optimum set of measures from a large number of possible measures. Heuristics is defined in literature as a technique which seeks near optimal solution at a reasonable cost [50]. It is flexible, easy to understand and implement. Constraints [51] regarding cost and resources are defined early in the measurement process and it plays an important role in final decision making of optimum measures set selection. These constraints act as thresholds which are utilized as process terminators in OMSD Model. These constraints are collected after the first step of GQM (goals identification). The approach is comprised of five main steps shown in Figure 3.1 below. These include:

Step: 1 Category Selection  
Step: 2 Attributes Identification  
Step: 3 Measures Selection  
Step: 4 Collecting Data on the Measures Based on Factors  
Step: 5 Decision Making  

Our approach starts working at the second level (Question Level) of GQM paradigm. The details of each of the steps are given in the following paragraphs.

3.1 Step 1: Category Selection

This step involves mapping of the questions identified in the questions level of GQM paradigm on their respective categories (product, process, resources). In order to perform any measurement activity we need to identify the entity to be measured and the associated attributes.

In [13], three main categories of entities are defined as,

- Process
- Product
- Resource

**Process category** includes different activities and these activities are associated with timescale. There is a particular order defined for these activities means activity B requires the completion of activity A. This timing could be implicit or explicit. **Resources** and **Product category** are associated with the process category. This means every process has certain resources and products that it utilizes [13].

On the other hand, the attributes are divided into two main categories, namely external and internal attributes. **Internal attributes** are those which could be measured only by observing the product. Whereas, **External attributes** include processes, products, resources and its behavior which tells how these attributes relate to the environment [13].

Since these categories facilitates in selecting the measures from the ‘Measures Pool’, we included these categorization in the model. Measures Pool is the repository which contains the measures defined for software measurements. Since this set might contain hundreds of measures, in the scope of this study we included the ones provided in ISO
9126 [35, 36, 37, 38], ISO 25000 [39], the ones suggested as the minimum set of measures defined in CMMI [41] and measures which are best known by the organization itself in their experience factory (see Chapter 2 for details).
This step results in the identification of measurement entities (questions) on their respective classes (as shown in Figure 3.2 below) which serves as input to the next phase of 'Attribute Identification'.

![Category Selection Diagram]

### 3.2 Step 2: Attribute Identification

Second step in OMSD Model is the identification of attributes associated with the entities (questions). These attributes include both internal and external attributes. In this model, the attributes set is pre-defined based on the attributes defined in ISO 9126 [35, 36, 37, 38] and ISO 25000 [39]. It further narrows down our focus which facilitates in measures selection later on. Category selection and attributes identification provide deep understanding regarding behavior of the respective questions. Figure 3.3 depicts the attribute identification process.

![Attributes Identification Diagram]

This step results in the following two outputs regarding the questions:

- Respective categories of questions
- Associated attributes depicting their behavior and relation with environment.
These identified attributes facilitate in Decision Making (Step 5) later on. At least one attribute is identified for each question because these attributes represent its respective questions in decision making. It is possible that one question can be related to more than one attribute and one attribute can be associated with more than one question. These dependencies are also identified and used later in the decision making process.

3.3 **Step 3: Measures Selection**

The main aim of this step is the selection of all possible measures from Measures Pool using identified categories, attributes and measures selection criteria (explained below). We defined the criteria for measures selection from the Measures Pool based on the guidelines defined by the standards such as ISO 15939 [40] and CMMI [41].

The following are the criteria we incorporated in our model:

- Feasibility of collecting data in an organization
- Availability of human resources to collect and manage data
- Extent of intrusion and disruption of staff activities
- Availability of appropriate tools and equipment
- Personal preference
- Ease of interpretation by measurement users and measurement analysts
- Ease of presentation and relevancy to the audience

The criteria serve as a base for measures selection, but these do not tell which of the available measures for that specific attribute to collect. For example, if a measure for software size is required to be collected, all size measures available in the Measures Pool, such as Function Points, SLOC, Bytes, are selected.

The criteria also help considering the aspects such as possible risks in measures collection, required tools, required human resources, any special type of training, its effect on organizational activities and aid in eliminating the measures from the beginning which are not feasible. Figure 3.4 below depicts the measure selection process.
3.4 Step 4: Collecting Data on the Measures Based on Factors

Once the measures are selected, factors which we identified to be significant in deciding on the optimum set are mapped. The evaluation results of these factors by means of a survey within the industry are discussed in detail in Chapter 5. For each measure, the relevant data for each factor are entered by the measurement responsible. These data will be used in the next step for the final decision making to ensure the optimum measures set. Figure 3.5 below shows the identified factors.

Figure 3.5: The Significant Factors on Measures Selection

In literature [8, 10, 11], there are a lot of factors defined and suggested for a measurement process such as cost, time, resources requirements, tools, special trainings etc. We have selected the most basic factors having significant impact on the measurement process. These factors are general and can be applied to any process that involves measurement irrespective of its domain i.e. software process, management process, manufacturing process etc.

Factor 1: Collection Time

It includes two sub-factors which are:

- Duration
- Frequency
Main aim of this factor is to collect time related information of a particular measure. Duration sub-factors describes the time required to collect a measure ‘A’. Frequency sub-factor describes how many times that measure ‘A’ is needed to be collected. Information obtained from these measures is used in calculating required effort. It results in cumulative time weight by multiplying duration and frequency sub-factors.

**Cumulative Collection Time Weight (CCTW) = Duration * Frequency**

**Factor 2: Cost**

We consider the cost of measure in terms of resources it required such as human and non-human. It has one sub-factor which is:

- Utilization

This is further divided into two sub-factors which are:

- Resources
- Expense

Resources sub-factor contains the details regarding number of resources required as well as their cost in terms of experience and type. Resource sub-factor is further divided into two sub-factors which are:

- No of Resources
- Resource Cost

We have defined three classes of resources with respect to their job responsibilities in an organization. These resource classes facilitate in collecting resource cost of a particular resource. These classes are:

- Upper Management Resource (UMR)
- Middle Management Resource (MMR)
- Resource [Developer, Tester, Analyst] (R)

Resource cost is calculated by dividing the resource salary with the total working hours of the month.

**Individual Resource Cost (IRC) = Salary/Working Hours of Month**

Whereas expense sub-factor contains the additional expense like training, tools, hardware expenses etc. Resource cost is used with the cumulative time weight in calculating effort of a particular measure. It is calculated by adding the cost of different resources involved in it.

\[
\text{Resource Cost (RC)} = \sum_{i=1}^{n} \text{IRC}_i
\]

*Assumption:*

Working hours of month depends on the organizational work policy. Currently we assumed that resources work 8 hours daily and 22 days per month means they work total 176 hours per month.

**Factor 3: Value**

Value factor contains the information regarding the measure’s dependency and importance in client organization’s view. It contains the following two sub-factors:
Dependency contains the information regarding direct and derived measures [32]. This dependency identification is critical for the effectiveness of final decision making. In OMSD, we use only direct measures in order to make decision process easier. If a derived measure came up we adjust it by calculating the cost of each base measure and then adding them together.

On the other hand, Importance depicts the significance of a particular measure in the view of customer. Later on, this information facilitates in decision making by doing tradeoffs between measures.

We have defined four levels of importance which include:

- Level 1: Minor
- Level 2: Essential
- Level 3: Major
- Level 4: Critical

**Factor 4: Type**

This factor is for information purpose only. It contains the information regarding type of measure such as entity class that it belongs to and attributes associated with it. It includes two sub-factors:

- Associated attributes
- Category

**Factor 5: Repetition**

This factor is also for information purpose only. It facilitates in decision making later on by identifying the multiple usage/repetition of the same measure. In this way, it reduces the probability of redundancy.

**Decision Factors**

This step results in some decision factors. These factors include effort required to collect a particular measure (Figure 3.6). Effort is calculated in terms of person-hours through cumulative collection time weight and resource cost.

\[
\text{Effort} = \text{CCTW} \times \text{RC}
\]

Effort is used to calculate cumulative cost of collecting a particular measure. We defined cumulative cost as a function of both effort and expense (see Factor 2: Cost).

\[
\text{Cumulative Cost (CC)} = \text{Effort} + \text{Expense}
\]
3.5 **Step 5: Decision Making**

Decision making is the final step of OMSD model. Decision making plays an important role in our daily lives and anyone who holds a technical, managerial, or administrative job face alternative approaches to make decision out of them. Decision making is a process that shows expertise of an individual in selecting one solution out of the possible alternative.

There are two categories of decision making problems:

- One says that there are finite possible alternative solutions to a problem in which each alternative is known in detail and anyone can be selected as the decision. A method named Scoring Method [15] is used to handle with such kind of problems.
- Second says that for each possible alternative, it is required to satisfy some restrictions and constraints for the system to operate under them. So, we have to define decision variables in the problem and build a mathematical model of the objective function [15].

For the second approach, a quantitative analysis [15] is required that includes problem definition, constructing mathematical model, solving the model and implementing the solution. The problem can be deterministic with controlled variables/inputs and stochastic with uncontrollable inputs [15]. Decision making in OMSD model includes controlled inputs in the form of constraints (time and cost limits) and variables such as usage and importance. So, the problem addressed by OMSD model is deterministic and decisions are made by constructing rules (7 steps explained below) in order to solve the defined problem.

The Decision Making step consists of following two sub-steps:

- Attribute – Measure Matrix Creation
- Screening Process
Main purpose of this step is to decide on optimum set of measures from the selected measures. It utilizes the identified attributes (Step 2) and selected measures (Step 3) for decision making. Some ground rules are defined which facilitate in final decision making.

**Assumption:**
It is important to keep in mind that this model also involves some conditions (constraints/limitations) in order to make optimal decision. These conditions are applied to every measurement process that makes it important to consider in **OMSD model**. Two types of constraints are:

1. Time constraint (in Hours)
2. Cost constraint (in any cost unit e.g. $, €)

Both the constraints play critical role in final decision making.

**Attribute – Measure Matrix Creation:**
First step in decision making is the creation of attribute-measure matrix. Inputs to this step include identified attributes and the selected measures. It is a two dimensional matrix that depicts the relation of measures with their respective attributes (see Table 3.1 below). One important point to be stated is that we needed to eliminate dependencies before this step because if dependencies are not eliminated, it could reduce the effectiveness of this process. It is because we might exclude a particular measure in the screening process (explained below) on which many measures could be dependent. This will give rise to incomplete selection of measures resulting in ineffective measurement process. Dependencies are eliminated by employing only direct measures in this step means if any derived measure comes up instead of using its base measures we use derived measure itself. Table 3.1 below depicts the structure of attribute-measure matrix.

Attribute – Measure Matrix creation consist of the following steps:

1. Sort measures on the basis of their importance. Highest importance (4-Critical) measure comes first.
2. If Measure ‘X’ is used to measure Attribute ‘Y’, then fill in the respective cell with ‘1’ otherwise with ‘0’ (see Table 3.1 below).
3. Calculate the number of usages of each measure by adding the values in that column.
4. Add Importance weight and cumulative cost of each measure in the respective cells.

**Screening Process**
Screening process is the last step in **OMSD Model**. It utilizes attribute – measure matrix and a set of pre-defined decision factors in order to decide on the optimum set of measures. The defined screening rules are implemented during the final screening process. These rules are based on a number of factors such as the Number of usage, Importance and Cost. A heuristics approach is used to make a tradeoff.

After every selection, a comparison is made with constraints [51] in order to control the progress. These constraints include two aspects which are:

- Cost Limitations
- Time Limitations
Certain tradeoffs are also needed with respect to importance and cost factors of measures but these tradeoffs are primarily dependent on the organizational business needs. The model selects at least one measure for each attribute because each attribute represent a particular question.

Table 3.1: Attribute – Measure Matrix

<table>
<thead>
<tr>
<th>Measure Attributes</th>
<th>Measure 1</th>
<th>Measure 2</th>
<th>Measure 3</th>
<th>.................</th>
<th>Measure n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attribute 1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0 0 0 0 0</td>
<td>1</td>
</tr>
<tr>
<td>Attribute 2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0 0 0 0 0</td>
<td>0</td>
</tr>
<tr>
<td>Attribute 3</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0 0 0 0 1</td>
<td>0 0 0</td>
</tr>
<tr>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>Attribute n</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0 1 0 0 0</td>
<td>0 0 0</td>
</tr>
<tr>
<td>Usage</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1 1 1 1</td>
<td>1 1 1 1</td>
</tr>
<tr>
<td>Importance</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3 2 2 1</td>
<td>1 1 1</td>
</tr>
<tr>
<td>Cumulative Cost</td>
<td>50 €</td>
<td>70 €</td>
<td>10 €</td>
<td>15 € 40 €</td>
<td>35 € 180 € 100 € 5 €</td>
</tr>
</tbody>
</table>

Following rules are primarily dependent on the organizational business needs which means there is no fix order for these rules. Order of these rules could be changed based on the organizational requirements. Basically, screening process consists of the following steps:

**Step: 1**  Select Attribute ‘\( A_i \)’

where \( i = \{1,2,3,4,\ldots,n\} \)

**Step: 2**  Select each measure ‘\( m_i \)’ which satisfy attribute ‘\( A_i \)’

\( A_i = \{ m_1, m_2, m_3, \ldots, m_n \} \)

**Step: 3**  Calculate the usage \( U_{mi} \) of each measure \( m_i \)

Usage of \( m_i (U_{mi}) = \) How many time it is used in Attribute-Measure Matrix.

**Step: 4**  Perform Comparisons on the base of Decision factors.
a. Compare the **Usage** of each measure \( m_i \) with all selected measures
b. Compare the **Importance** of each measure with all selected measures

c. Compare the **Cost** of each measure with all selected measures

**Importance** = weight assigned to Measure \( m_i \) (Step 4: Factor-Value)

**Cost** = Calculated through Step 4 of the Model

**Step: 5** On the base of comparisons performed in step 4, select appropriate measure. Note that measure selection is completely dependent on the organizational decision (means which decision factor is of high importance for organization).

**Step: 6** Check the selected measure against the pre-defined constraints. Primary aim of this step is to control the measurement process in order to make sure that cost of the selected measures remains under the cost limits. This step is repeated at the end of each iteration in the screening process.

**Step: 7** Check the following conditions:

a. If Cost of selected measure \( C_{ms} \) is less than Constraint Cost \( C_{cost} \) then continue from step 1

\[
C_{ms} < C_{cost}
\]

b. If \( C_{ms} \geq C_{cost} \) terminate the process.

Step 6 and 7 are mutually exclusive. Once the selected measure is analyzed against the defined constraints, decision about continuation or termination of measurement process is made on the basis of condition in step 7.

An optimum measure set is selected after completion of these steps (either termination condition is met or all measures are gone through). Figure 3.7 depicts the flow of screening process. This selected measures set contains those measures that optimizes the cost constraint set by the organization.
Figure 3.7: Screening Process Flow Chart
4  **CHAPTER 4 – AN ALTERNATIVE MODEL**

Heuristics approach used in the proposed solution is a good way to find the optimum set of measures. Although heuristics facilitate in decision making yet it is not the most efficient technique because it requires heavy human interaction. In order to make the process less erroneous and automated, optimization technique is proposed in the Alternative model.

Optimization has a relationship with decision making and the decision making process is greatly affected by suitable optimization techniques. These techniques provide tools for making best decisions. It is quite rare in reality to have one decision variable with a unique solution [15] instead there are models in the real world that propose many solutions. But selecting one out of these many proposed solution is the essence of optimization models.

Optimization models can be divided in two categories based on different aspects as follows [15]:

- **Single and Multi-objective models** - The objectives are set before designing the model. There could be objectives about cost, quality, and time. Single objective models have one objective but that does not happen most of the time. The objectives of the model tell about the effectiveness and complexity of the model. There is less work on multi-object models and techniques for handling multi-object problems include trial and error using several degrees of compromises among different objectives.

- **Static and the Dynamic Models** – Static models deal with the one-short situation and include determining solution for one period of time whereas the others are multi-period or dynamic models. In the cases of dynamic models, the date change from one period to the other is significant but still the sequence of decisions will be interrelated.

- **Stochastic and Deterministic Models** – The optimization models that have no uncertainty about data elements are deterministic models whereas the others are stochastic models involving multiple random variables generating different type of data.

The Alternative model is a Multi-objective, Dynamic and Deterministic model. This approach aims to increase effectiveness and efficiency of the measures selection process. Whenever an optimization or mathematical technique is applied, the real world facts and issues are formalized so that the actual issues can be considered while proposing solution. Similar is the case with the alternative approach. A holistic view of this approach is given in the Figure 4.1 below. The main steps involved in an optimization approach are:

- Conversion of facts or real world into formal world
- Creation of Optimization Model
- Optimization Tool/Technique

The first step is the conversion of facts into a mathematical and formalized form that can be understood by the optimization model. These facts include factors, attributes, goals, questions, constraints and criteria of measures selection. These are the facts involved in any software project and considered important while making decisions on the measures selection.
Once these facts are noted and a formalized model is made depicting real world issues, an optimization model is created. The process of optimization model creation involves developing a model file that contains business logic. The model file uses data from the data file (this data is different for different optimization problems). There is a run file made to execute run commands and call functions of the model file that are using data file. All of these steps are explained in section 4.1.1 and shown in Figure 4.3.

This view of optimization theory is mapped on our Alternative Solution of optimum measures selection. As it is seen in the Figure 4.1 below, formal model is made before creation of an optimization model. This formal model is developed by following first four steps shown in Figure 4.2. These four steps (Category Selection, Attribute Identification, Measures Selection, Collecting Data on the Measures) results in mapping of real world issues into a mathematical form. These steps are discussed in detail in the previous chapter so we will focus on the optimization part of the alternative approach. Optimization technique is divided into 2 parts:

- Creation of Optimization Model
- Optimization tool/technique usage

When data is collected for each measure, it is then used to define rules and logic for the optimization model. As discussed earlier, the logic is maintained in the model file. Optimization tool section below shows how the techniques are used and gives optimized set of measures as a result. The tool is used once the optimization model creation step is completed. The logic file is run and a sample data is provided to see if effective results are obtained. The limitations, factors and conditions are applied in the model file as a part of optimization algorithm and logic.

![Figure 4.1: Holistic view of the Optimization theory](image)

**4.1 Tools and Techniques Used**

Tool selected for this particular task is the ILOG CPLEX [34]. It is a mathematical optimization technology and it facilitates in making decision regarding efficient resource utilization. CPLEX represents complex business problems in the form of
It employs advanced optimization algorithms which facilitate in rapidly finding solutions to these mathematical models [33, 34].

Figure 4.2: Alternative Solution using Optimization Technique
ILOG CPLEX utilizes following algorithms [34]:

- Simplex Optimizer
- Barrier Optimizer
- Mixed Integer Optimizer

CPLEX is designed to solve integer programming problems. It is also available in different modeling systems like AIMMS, AMPL, MPL, TOMLAB etc. for this particular study we have selected the AMPL (A Modeling Language for Mathematical Programming) [44].

4.1.1 AMPL

AMPL is an algebraic modeling language and it is used to solve the problems related to linear and nonlinear optimization. It is used to solve problems related to discrete and continuous variables. AMPL has its own syntax and semantics [44].

AMPL require three types of inputs:

- Model File
- Data File
- Run File

Model file contains the logic or model of problem that we want to optimize. Data file on the other hand contains the integer data that is required by model file. Model file read the data file to get inputs against variables defined in it. Run file is required to run the model and data files in CPLEX. Following Figure 4.3 depicts the working of these files.

Figure 4.3: Inputs required for AMPL

4.2 Limitations / Problem Faced

We have tried this alternative along with the heuristics approach. There are certain issues and limitations associated with this possible solution. The problems we have faced are discussed below:

- The first important point to note is that measures have interdependencies that make it difficult to select one measure and leave the other one. In the real time
projects, we have a lot many measures of different types such as base and derived measures. It is difficult to build the model logic while considering these many interdependencies.

- Another limitation to the optimization tool (we used CPLEX student version) is that it do not work properly when we have more than 250 measures.
- It is not possible for optimization model to deal with more than 1 factor at a time and it becomes real complex when you have multiple factors effecting measures. It is rather easy to handle as many factors and measures as we want by using the heuristic approach.
- The optimization model only works with integers and the comparisons made between variable are integral. The comparisons and decisions are based on conditions and limitations of the project.
- Another limitation that we have faced is the time constraint of our research based study. However, we discuss this other alternative so as to provide background for further research.
5 CHAPTER 5 – EMPIRICAL STUDY

As the empirical research strategy, we used traditional fixed non-experimental design strategy [45]. We performed a survey by distributing a structured questionnaire in order to evaluate the important factors we identified when selecting the optimum number of measures to be collected in an organization (see Section 5.1). We also evaluated the heuristics rules of OMSD model by means of some sample cases we created (see Section 5.2).

5.1 Survey

We conducted a survey by means of a structured questionnaire to evaluate the important factors we identified based on the literature survey results as well as our experience. These factors are the core of our approach as decisions for collection are made on the basis of these factors in the OMSD model (explained earlier in section 3.3.4). Therefore, these factors provide a base for deciding on the optimum set of measures during the measurement process. Based on the results of the survey, we finalized the factors in the OMSD model.

There are many organizations that are following standards for software development and they work on measurement processes that lead them to overall process improvements. We selected 10 organizations in different countries and sent questionnaires (explained later, shown in Appendix A) to the people working on measurement in these companies. The survey is conducted online since the organizations are located in different countries. Single subject from these organizations is selected that has responsibility of their measurement process. Moreover, subject selection in this way will ensure sufficient background about the survey.

5.1.1 Questionnaire Design

A structured questionnaire was prepared to carry out the survey. The questionnaire consists of mainly four sections. The questionnaire template is given in Appendix A. Detailed information on the questionnaire is provided below.

- **Section 1 - Personal information.** Section 1 consists of informative questions about the subjects. We asked the roles of survey subjects and their respective experiences so that we can correctly interpret the answers of the subjects.

- **Section 2 - Measurement process and challenges.** Section 2 confers to getting inputs from the subjects on their organization’s measurement process and their improvements needs. Below is the reasoning of questions from Question 1 – 6.
  - **Question 1** – The reason of adding this question is to learn whether the organization in which we are going to conduct a survey follow a measurement process or not. It is important because if they do not follow any process, then this means that are not doing measurement or using some ad hoc way to conduct measurement activities. In either of the case, it is important to know that they are satisfied with their current settings or not (Question 5)?
  - **Question 2** – The rationale of adding this question is to learn what standards are followed in the measurement process of surveyed organization. It is so because organization following standards might better evaluate and rank the factors included in the later questions.
  - **Question 3** – The rationale of adding this question is to learn what measurements frameworks are used in the organization. This is important because organization following a framework will have
defined measurement process as compared to an ad hoc measurement process.

- **Question 4** – It is aimed to know if an organization has defined their own standard and to know the effectiveness of our defined factors (used in OMSD model).

- **Question 5** – This question reflects respondent’s satisfaction of their measurement process.

- **Question 6** – This question tells the challenges that the organization and resources are facing in terms of measurement process. This is important to reflect the findings and relate these results to our-defined factors (used in our model OMSD Model).

- **Section 3 - Factors importance.** This section includes question 7 and 8 that shows which factors are important for the measurement process and how much the factors (we defined) are effective. We aimed to evaluate the effectiveness of the identified factors in subject’s point of view with respect to their personal experience of software measurement processes.

  - **Question 7** – This question helps in learning the important factors that impact the measurement process. This question is answered on the basis of their personal experiences and knowledge. These are important to compare with our defined factors.

  - **Question 8** – This question results in ranking of each factor on the basis of subject’s input. It is important because the results of the survey and validation of our approach is based on factors and their ranks (out of question 8).

- **Section 4 - Personal suggestions.** This section results in suggestions on the defined factors in question 8 by the subjects of the survey.

  - **Question 9** – It is important to get guidance on what is important for the subjects. What can be included in our-defined factors?

### 5.1.2 Analysis of Survey Results

In this section, we provide the analysis of the survey results. This analysis facilitates us in evaluating the identified measurement factors. These factors employ in OMSD Model and facilitate in determining crucial information regarding measures. This information facilitate in deciding on optimum measures set. There were 10 different companies selected for this particular survey. Their response details are presented in the table 5.1 below:

<table>
<thead>
<tr>
<th>Total Number of participant</th>
<th>10 Companies</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respondents</td>
<td>7</td>
<td>70%</td>
</tr>
<tr>
<td>Non-respondents</td>
<td>3</td>
<td>30%</td>
</tr>
</tbody>
</table>

The coming section includes a detailed discussion regarding different questions presented in the survey based on the received survey response.
5.1.2.1 Survey Section 1- Personal Information

Primary aim of this section is to collect personal information of the respondent. Personal information is a major factor that depicts maturity of the response. This section provides information regarding two basic aspects:

- Role of respondent
- Experience (in years)

Following table presents the personal information collected regarding respondents:

<table>
<thead>
<tr>
<th>Role</th>
<th>Number of participants</th>
<th>Experience (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Manager</td>
<td>4</td>
<td>1—6</td>
</tr>
<tr>
<td>Team Leader</td>
<td>3</td>
<td>1—3</td>
</tr>
<tr>
<td>Quality Assistant</td>
<td>3</td>
<td>2—5</td>
</tr>
<tr>
<td>Developer</td>
<td>4</td>
<td>1—10</td>
</tr>
<tr>
<td>Tester</td>
<td>3</td>
<td>1—4</td>
</tr>
<tr>
<td>Consultant</td>
<td>4</td>
<td>2—13</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>10</td>
</tr>
</tbody>
</table>

The respondents have performed a variety of roles. For example, one respondent worked as a ‘Quality Assistant’ whereas, the other is a ‘Developer’. Our basic aim for this survey is to target participants having at least 1 year experience in their respective roles. Survey results clearly depicts that we have successfully achieved this goal because all participants have at least 1 or more then 1 year work experience in their respective roles.

5.1.2.2 Survey Section 2 - Measurement Process and Challenges

Defined measurement Process: Primary aim of survey question 1 is to get information regarding whether the targeted organization employ a defined measurement process or not. Following Figure 5.1 display the percentage of organizations following a defined measurement process.
Standards/Frameworks/Models: Primary aim of survey question 2 is to elicit information about selected standard in the targeted organization. Standard set that is provided in the survey include ISO 9126, ISO 25000, ISO 15939 and CMMI. These standards facilitate in attribute and measures selection in our proposed Optimum Measures Set Decision (OMSD) Model. Main focus is to check, whether the targeted organization employ one of these famous standards or not. Results on this question are shown in Figure 5.2 below.

Analysis of result reveals an interesting fact that many organizations utilize a combination of different standards, models and frameworks instead of using single one. They either defined their own measurement process by selecting best practices from these standards/models/frameworks or they choose only those practices which are in accordance to their business goals.
**Measurement frameworks:** Question 3 and 4 of the survey facilitates in determining the utilization of selected measurement frameworks in targeted organization. It helps in determining whether organizations follow:

- Any other defined framework
- Use their own defined framework

An open choice is also provided in order to facilitate respondent in describing framework that they employ in their organization. Results of this question are quite interesting as many organizations prefer to use GQM. Some responses clearly convey that some organizations utilize their own defined measurement process which is in accordance of their needs. This information is vital in our study because we have based our OMSD Model on GQM approach. Although it could be done without GQM but using it can provide many benefits (which include easiness in category selection, attribute selection etc). Our analysis also reveals that there are some organizations that employ more than one measurement framework. Results are shown in Figure 5.3 below.

![Figure 5.3. Measurement Frameworks](image)

**Satisfaction level with respect to measurement process:** Survey question 5 and 6 are aimed to gather information regarding respondent’s satisfaction level of their current measurement process and main challenges that they faced in measurement. This information is helpful in determining some major challenges that organizations faced in industrial environment. This information also facilitates in determining the usefulness of a particular measurement framework e.g. survey results show that organizations using GQM and GQIM are highly satisfied with these frameworks. This analysis supports our decision of using GQM approach as base for OMSD Model.

### 5.1.2.3 Survey Section 3 – Factors Importance

**Three important factors in respondent’s view:** Question 7 of survey facilitates in determining the respondent’s opinion regarding factors which are utilized in measure selection. Analysis of this question reveals an interesting fact that all respondents are agreed on ‘COST’ being the most important factor in measure
selection. This analysis supports our assumption that cost is among the most important factors that affects measures selection. Factor identified in response include:

- Collection time
- Frequency
- Experience of resources
- Number of resources
- Training cost
- Effort
- Quality of Measures
- Normalization of collected data
- Measure Reliability

**Importance of factors identified in OMSD Model:** Primary aim of this question (question 8) is to get industrial feedback on the importance of factors identified in OMSD Model. Details on the factors and their results are given in the coming paragraphs.

**Collection Time:** Collection time factor contains two sub-factors duration and frequency. Survey analysis reveals that more than 70% of the population rank duration sub-factor as normal and more than 25% think that importance of this factor is high. Results are shown in Figure 5.4 below.

![Collection Time (Duration)](image)

**Figure 5.4. Results of Duration Sub-factor**

Whereas another interesting fact revealed by the survey results is that 50% of the population ranked frequency factor as high or very high and rest ranked it as normal or low importance. Results are shown in Figure 5.5 below.
Based on these results, we considered ‘Collection Time’ as a factor in OMSD model since its importance is also validated by the industry.

**Cost:** Cost factor is further divided into three sub-factors such as number of resources, resource cost and expense. Analysis reveals that more than 50% of the population ranked the resources required / no. of resources as very high or high and rest ranked it as of normal importance. Results are shown in Figure 5.6 below.

Resource cost sub-factor contains the cumulative cost of total no. of resources required for a particular measure. This sub-factor workd as backbone in OMSD Model. According to results, approximately 40% of the population ranked this sub-factor as high or very high. Whereas other ranked it as normal. Results are shown in Figure 5.7 below.
Expense sub-factor contains additional expense (additional hardware, training etc) associated with cost of resources. Results reveal that more than 50% of population consider this highly/very highly important and rest of them consider this normally important. Results are displayed in Figure 5.8 below.

Based on these results, we considered ‘Cost’ as a factor in OMSD model since its importance is also validated by the industry.

**Value:** This factor contains two sub-factors i.e. dependency and importance. Both these factors play a key role in final decision making in OMSD model. As expected, majority of the population consider dependency sub-factor as of high or very high importance and only less than 40% of them ranked it as normal or low. Results are shown in the Figure 5.9 below.
Figure 5.9. Results of Dependency Sub-factor

Importance sub-factor is one of the critical factors that employ in many steps of OMSD model. It also plays a key role in deciding on optimum measures set. More than half of the population ranked it as very high or high and the rest marked it as normal or low. Results are shown in Figure 5.10 below.

Figure 5.10. Results of Importance Sub-factor

Based on these results, we considered ‘Value’ as a factor in OMSD model since its importance is also validated by the industry.

Repetition: Main aim of this factor is to collect information regarding the usage of a particular measure. It also plays a key role in final decision making regarding optimum measures selection in OMSD model. Analysis reveals that more than 70% of population agrees on this factor as of high importance. Results are shown in Figure 5.11 below.
Based on these results, we considered ‘Repetition’ as a factor in OMSD model since its importance is also validated by the industry.

5.1.2.4 Survey Section 4 – Suggestions

The suggestions from respondents are important for knowing how rightly we have defined the factors and how important they are for a measurement process in respondent’s point of view. We have included the basic factors that are considered critical in any measurement process. Measures should be related to these factors (time, cost etc) to know their affect on measures. These suggested factors can be included in the factor list in future and guide for better approach derivation.

- Risk (Impact on estimates)
- Accuracy of measures output

In a nutshell, results from the survey about factors help in knowing the effectiveness of the OMSD Model. As these factors are core of the proposed OMSD model, the results impact strongly on the model. All other key parts of the model including identifying attributes, criteria definition and rules for decision making are derived from standards such as CMMI and ISO. But these factors play critical rule in model as these are used for collecting data on measures from the organization measurement process. These factors are also vital in making decision in the later steps of the model i.e. screening process. This is the main reason of including factors in the survey to check its validity in different organizations. As described above, the statistics/results have shown that these factors are important in measurement processes (in respondent’s point of view). Effective factors definition ensures the efficiency of our approach as a decision model for measures.

5.2 Experimentation of the Heuristics Rules

After evaluating the factors which are the core of the OMSD model, we experimented the heuristics rules that are defined in the OMSD model. For the experimentation, we created some sample cases (see Appendix B). The sample case
was built using sample Goals, Questions and Measures from the available standards such as ISO 9126, ISO 15939 etc. This case executes all the steps (in chapter 3) of the model till the optimum set of measures is found.

In the sample case, the time and cost constraints were set by the organization in terms of person-hrs and $, respectively. Other assumptions were working hours of the resources that were used in calculating cost of measures. The sample case contains 5 goals and 11 questions. The questions were mapped to 23 measures but 3 measures were repeated so, initial set was containing 20 measures that were answering to 11 questions. When the OMSD model is implemented for this sample case, we found the minimum set under these constraints as containing of 8 measures.
6 CHAPTER 6 – EPILOGUE

6.1 Discussion and Conclusions

Measurement process is one of the critical processes which lead an organization towards processes improvements. There are many measures that can be collected in a measurement process. Experience shows that measurement can be more successful if the measures are collected based on the goals of the organization or the project which it will serve. A few methodologies (discussed in the literature review) exist to aid the software organizations such as Goal Question Metric (GQM), Decision Maker Model, Standards Driven Metrics, and Goal Question Indicator Measure (GQIM).

Since collecting measures is also very costly for the organizations, there is a need to collect the optimum set of measures, i.e. the minimum set of measures based on the needs of an organization as well as the budget available for an organization to collect those measures. However, the organizations face difficulties in deciding on what measures to collect since there is no universal set of measures defined for all types of organizations and projects. In this thesis study we address the following problem:

‘To decide on selecting the minimal required set of measures from a number of possible measures’.

This thesis study proposes a model, called ‘Optimum Measures Set Decision (OMSD) Model’. The model focuses on providing an approach that can solve the issue of finding optimum measures set out of possible many measures. For the initial part (Goal, question derivation), the model has used GQM approach. The model uses attributes, factors, measures selection criteria and decision making rules for correctly handling process flow (details about OMSD has already been written in the above chapters). The model has five main steps (explained in chapter 3). As a whole, this model has provided a systematic approach to find the ‘right measures’ for our measurement process under the constraining conditions, i.e. factors such as cost, time and importance. Factors are the backbone of this model as data is collected on each measure in a process and decisions are made based on these factors (cost and importance) using heuristics. Decision making process has certain dependencies in terms of cost and time due to allocated cost and time to the measurement process. Moreover, deriving selection criteria, attributes and measures based on the standards assure standardized approach. It is important that this model is generic in nature and the decision making criteria defined in the model can be applied to any domain such as engineering, construction etc. There are different organizations that apply measurement processes in order to improve their processes. The criteria of cost, time and usage can help in making effective decision in any domain.

In short, the OMSD model has provided a systematic approach by using heuristics approach for dealing with the challenge of ‘finding optimum measure set’ out of the possibly large set of measures. Although it has some constraints such as not dealing with derived measures and much human interaction, still it provides a procedural way to address the described challenges organizations are dealing with.

In accordance to the proposed model, an alternative method is also proposed (see chapter 4 for details). This approach implements optimization techniques instead of heuristics. It automates the decision making process using a mathematical language AMPL along with an optimization tool named ILOG CPLEX. An optimization model is made in place of heuristics decision making that make it automated and effective.
Complexity of the mathematical work was also an important factor that hindered completion of the alternative approach. But, we further discuss this approach in section 6.2 as a future work since it is a promising approach.

By comparing both the approaches (Heuristics and Optimization), we found that the constraint of much human interaction can be reduced by using some optimization algorithm as it is automated and time effective. But, the limitations (such as maximum number of measures it can deal with, number of factors etc) to the optimization technique hinders in completion of this approach in the scope of this study and further research is required.

We used traditional fixed non-experimental design empirical research strategy [45]. We conducted a survey by means of a structured questionnaire to evaluate the important factors we identified based on the literature survey results as well as our experience. These factors are the core of our approach as decisions for collection are made on the basis of these factors in the OMSD model.

By means of the survey, we received industrial feedback on the identified factors. These factors play a key role in getting important for selected measures which is vital for deciding on optimum measures set. Survey was conducted in 10 different software organizations at different maturity levels. Respondents are selected on the basis of their experience regarding software measurement activities in order to create better understanding of our defined factors and having reliable feedback from them.

The questionnaire designed for the survey included open-ended and closed-ended questions (see Appendix A). Aim of open-ended questions was to get some information/suggestion from the respondents on the basis of their experience in order to know the challenges that they are facing and make improvements such as incursion of new factors. Along with open-ended question, we included closed-ended questions in the questionnaire to deduce results in order to know effectiveness of the defined factors.

As explained in detail in chapter 3, the survey questionnaire was distributed in 10 organization and we received feedback from 7 of them. The respondents of the survey were software measurement responsible having industrial experience of about 2-10 years. The respondents were product managers, team leader, quality assistant, developer, tester and consultants experienced in software processes and measurement programs. It was observed that about 70% of the organizations follow a defined measurement process and remaining 30% do not follow any systematic process for measurement (in our survey population). Survey results revealed that CMMI and ISO 9126 were followed by most of the organizations performing software measurement. It was also seen that most of the surveyed organizations were using GQM and GQIM along with their self-defined frameworks. It is important to note that organizations also use self-defined frameworks and processes according to their organizational and procedural needs. The survey results have revealed an interesting fact that organizations using GQM are more satisfied with their measurement processes that also supports our selection of GQM as a base for the proposed OMSD model. Furthermore, factors were ranked by the survey respondents and importantly most of the factors were ranked between normal to high/very high (see chapter 5 for details). Survey has provided industrial feedback on the defined factors and these factors are used to construct OMSD model. These factors play a major role in data collection on the measures set (step 3 of OMSD model) and effectiveness of these selected factors ensures significance of the whole model. So, the survey has evaluated the factors and provided a ground to build our OMSD model.
Along with the survey, a thorough experimentation of the heuristics-rules that we defined for the OMSD model was carried out using a sample case (see Appendix B). The sample case was created by using sample goals and questions from the standards/frameworks and best practices. The sample case contains practical implementation of the heuristics-rules in the OMSD model.

Even though the industrial survey on the factors considered in OMSD model and thorough experimentation of the rules of the OMSD model evaluated our approach, in order to generalize the results, more questionnaires should be collected and the rules should be experimented by means of different cases.

There is also a need to conduct case studies in industry to evaluate the applicability and effectiveness of the OMSD model.

There were 5 research questions defined in the study (see section 1.4 for details). Research questions 1, 3 and 4 helped in starting initial investigations of the research area. Preliminary background was built while studying the research areas in order to answer these questions. Answers to these questions helped us understanding relationship of measurement frameworks, Decision making and SPI (discussed in chapter 2). Measurement programs are developed by software organizations in order to measure, control and improve the software process. Effective decision making plays a vital role in any improvement program and different statistics are required to make efficient decisions. These statistics are provided by data collected on measures. So, measurement data helps in making decisions that result in process control and improvements. There are factors causing failure in measurement programs and answer to question 4 focuses on providing solution to deal with these factors (discussed in chapter 2). Moreover, research question 2 focused on different optimization techniques that helped us proposing alternative approach (discussed in chapter 4). Research question 4 and 5 provided a base for analysis and solution definition to the discussed problem. While studying challenges and problems that organizations are facing in finding optimum measures set, we proposed the OMSD model that guides managers in selecting the right number of required measures by its decision making rules.

In a nutshell, by answering these research questions, we have come up with our proposed OMSD model and the Alternative model. These approaches helps in making decisions for measures selection in software organizations. The contributions of this research work are:

- Measures Selection Criteria – used in step 3 of the OMSD model to select measures from measures pool.
- Measures Pool concept – All possible measures are provided in one repository that makes initial measures selection a lot easier.
- Identification of Factors – Core in our OMSD model that can be enhanced further.
- Proposing 2 approaches for deciding on measures selection in software organizations (Heuristics Approach and Optimization Approach)

### 6.2 Future Work

This thesis is a keen effort in the area of software measurement. Although we are able to come up with a solution but still there are many areas which require more work as well as improvement. Future work related to this study includes:
- Goal prioritization at GQM Level 1. It could provide benefits such as early decision making which make rest of the job a lot easier.
- Implementation of optimization technique (alternative solution) instead of heuristics discussed in Chapter 4.
- Development of a measures pool which act as a universal repository of measures. It facilitates organizations in selecting measures from a defined location as all commonly used measures are stored in it. Measures pool structure is given in the Figure 6.1.
- Automation of the OMSD model by means of a tool support.
- Evaluation and experimentation of OMSD model in different industrial contexts.
- Incursion of new factors in order to make decision process more efficient. Some factors are identified in the survey which could be added in the model.
- Integration of OMSD model with measurement approaches, frameworks and models other than GQM.

![Figure 6.1: Depiction of Measures Pool Structure](image-url)
7 REFERENCES


8 APPENDICES

8.1 Appendix A – Survey Questionnaire

Instructions

1. This questionnaire is divided into four sections.
2. Section one contains information about the respondent.
3. Section two contains questions from 1 to 6. Primary aim of these questions is to get information regarding:
   a. Organization’s measurement process
   b. Main challenge(s) that they faced
4. Section three contains the questions 7 & 8. These questions aim to identify the factors and their importance in selecting the measures from a set of finite measures. Accordingly we will get feedback from industrial experts on the factors we identified for optimizing the measures to be collected.
5. Last section contains some informative question asking participant's own view.
6. Remarks about the survey are taken at the end to check the effectiveness of the questionnaire.

PERSONAL INFORMATION

Name: __________________________________________

Email Address: __________________________________________

Age: ________ Gender: ________

Profession __________________________________________

<table>
<thead>
<tr>
<th>Role</th>
<th>Years of Experience in the Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Manager</td>
<td>□ ____________________________</td>
</tr>
<tr>
<td>Team Leader</td>
<td>□ ____________________________</td>
</tr>
<tr>
<td>Quality Assistant</td>
<td>□ ____________________________</td>
</tr>
<tr>
<td>Developer</td>
<td>□ ____________________________</td>
</tr>
<tr>
<td>Tester</td>
<td>□ ____________________________</td>
</tr>
<tr>
<td>Consultant</td>
<td>□ ____________________________</td>
</tr>
<tr>
<td>Other</td>
<td>□ ____________________________</td>
</tr>
<tr>
<td>Q#</td>
<td>Description</td>
</tr>
<tr>
<td>----</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>Do you follow a defined measurement process in your organization?</td>
</tr>
<tr>
<td>2</td>
<td>Which of the standards given below do you follow in the measurement process?</td>
</tr>
<tr>
<td>3</td>
<td>Do you use one of these measurement frameworks?</td>
</tr>
<tr>
<td>4</td>
<td>Is it your self-defined process?</td>
</tr>
<tr>
<td>5</td>
<td>What is your satisfaction level with current measurement process?</td>
</tr>
<tr>
<td></td>
<td>Comments:</td>
</tr>
<tr>
<td>6</td>
<td>What is primary challenge that you have faced in the measurement process?</td>
</tr>
<tr>
<td>7</td>
<td>In your opinion, what are the three most important factors (such as measurement cost, expertise of resources, etc.) in selecting the measures among the suitable set of measures for measuring a specific attribute? (For example, software size can be measured in SLOC, FP, Bytes, etc. For you, which factors are important in selecting the one(s) among them?)</td>
</tr>
<tr>
<td>8</td>
<td>Rank the listed factors which are determined to be</td>
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significant in selecting the measures among the suitable
set of measures for measuring a specific attribute
(definitions for each factor is given in Appendix B).

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<td>4. Repetition</td>
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<tr>
<td>(Multiple usages)</td>
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9. What factors you suggest that can be included else than the ones mentioned above?

Other Remarks:

Thanks for your cooperation!
## Appendix B – Sample Case

### Sample Case Description

| Case 1 | There are following 5 Goals considered for this case:  
|        | • To improve the productivity of development team.  
|        | • To improve the usability of product.  
|        | • To improve the functionality of the product.  
|        | • To improve the efficiency of the product.  
|        | • To reduce the complexity of the model |

#### G1 To improve the productivity of the development team

| Q1     | What is the productivity of the development team  
| Measures | Development Effort, SLOC, Function Points (FP)  
| Q2     | What is the value earned?  
| Measures | No. of Defects after release, Return on Investment |

#### G2 To improve the usability of product

| Q1     | How well the software is documented?  
| Measures | Completeness of description  
| Q2     | What is the clarity of functionality implemented?  
| Measures | Function understandability, Understandable input and output  
| Q3     | What is learnability of the product?  
| Measures | Effectiveness of the user documentation, Help accessibility  
| Q4     | What is operability of the product?  
| Measures | Physical access |

#### G3 To improve the functionality of the product

| Q1     | What is functionality of the product?  
| Measures | Function points (FP), Functional adequacy, Functional Implementation Coverage |

#### G4 To improve the efficiency of product

| Q1     | What is time behavior of the product?  
| Measures | Mean response time, Mean throughput, Mean turnaround time  
| Q2     | What is resource utilization of the product?  
| Measures | Maximum memory utilization, I/O loading limits, Maximum transmission utilization |

#### G5 To reduce the complexity of the product

| Q1     | What is size of the product?  
| Measures | FP, LOC  
| Q2     | What is complexity of the product?  
| Measures | Cyclomatic complexity |
### Factors, Mapping to Measures, Heuristics Formula Derivation

<table>
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<th>Factors</th>
<th>Goal 1</th>
<th>Goal 2</th>
<th>Goal 3</th>
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<td>M12b</td>
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<td>M22b</td>
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#### Factor: Type

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<tr>
<td>No. of resources</td>
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61
| Type | UMR | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|      | MMR | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 1 | 3 |
|      | R   | 1 | 0 | 0 | 2 | 0 | 2 | 1 | 1 | 1 | 2 | 2 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 2 | 2 | 0 | 0 | 0 |
|      | Resources Cost | | | | | | | | | | | | | | | | | | | | | | | | | |
|      | Expense ($) | 50 | 30 | 80 | 40 | 35 | 25 | 20 | 15 | 15 | 21 | 21 | 80 | 21 | 21 | 80 | 40 | 10 | 12 | 8 | 12 | 10 | 12 | 8 | 12 | 8 |
|      | Effort (Person-hours) | | | | | | | | | | | | | | | | | | | | | | | | | |
| Effort (Resource Cost * Cumulative Time weight) = | | | | | | | | | | | | | | | | | | | | | | | | | |
|      | 300 | 150 | 225 | 300 | 300 | 300 | 225 | 225 | 150 | 150 | 300 | 300 | 300 | 225 | 225 | 300 | 225 | 225 | 300 | 300 | 225 | 225 | 300 | 225 | 225 |
|      | 225 | 225 | 225 | 225 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 |
|      | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 |
|      | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 |
|      | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 |
|      | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 |
|      | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
|      | 135 | 135 | 135 | 135 | 135 | 135 | 135 | 135 | 135 | 135 | 135 | 135 | 135 | 135 | 135 | 135 | 135 | 135 | 135 | 135 | 135 | 135 | 135 | 135 | 135 |
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|      | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 |
|      | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
|      | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
|      | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 |
|      | Factor: Value | | | | | | | | | | | | | | | | | | | | | | | | | |
| Importance | 3 | 2 | 3 | 4 | 1 | 1 | 2 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 2 | 1 | 1 | 2 | 3 | 1 | 3 | 2 | 4 | | |
| Dependency | No. of Resources, No. of | | | | | | | | | | | | | | | | | | | | | | | | | |

It is additional cost (Tool, Training, hardware, analyst)
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**Legends:**

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**Assumptions** - 6 months duration, 5000 $ is assigned cost for measurement, there are 1 release for project

**Resource Cost**

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<tr>
<td>Middle Resource</td>
<td>Management</td>
<td>Working hrs are (22 working days * 8 hrs per day)--also depends on organization</td>
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<tr>
<td>Resource (Developer, Tester)</td>
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**Scale to calculate importance**

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**Constraints**

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200000 Cost units
## Attribute Measures Matrix and Screening process

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Tradeoff is the 4th rule of selection
Legends:

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<th>Screening Rules</th>
<th>Optimum Measures Set (Result)</th>
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By using Number of Usage, Importance and Cumulative Cost, and comparing measures on this basis -- **8 measures** are selected that are covering each attribute and the cost of **5907.5$** where as the limit was **20,000 $**. So we are well in the limit. We are checking cost after every selection of measures in order to see when we are going out of limit.