The Rosetta Stone Methodology – A Benefits Driven Approach to Software Process Improvement

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Abstract

Part of the maturity process in the fields of software engineering and information technology has involved, and continues to involve, establishing best practices in the various domains that constitute the area. Specifically, from a software development perspective, there are several competing Software Process Improvement (SPI) methodologies such as the Software Engineering Institute's (SEI) Capability Maturity Model Integrated (CMMI) approach and the International Standards Organization's ISO/IEC 15504 (previously known as SPICE). All these initiatives aim to improve an organization's systems capabilities but they aim to do so from an Information Technology (IT) perspective. However, the majority of organizations are not IT-centric and IT is but one of several elements which contributes to their success. As a result, organizational leaders are more comfortable seeing the benefits of SPI within the context of organizational benefits and objectives and what SPI can contribute to the organization as a whole, not as a purely IT objective. Unfortunately, there is a dearth of methodologies which approach software improvement from an organizational goals and objectives perspective.

In response to the lack of an organization-focused approach to SPI, the research presented in this thesis, the Rosetta Stone Methodology, has been developed. This methodology allows organizations to make SPI decisions based on business- and organizational-driven goals and objectives. The methodology allows practitioners to map from a benefits model which is organization-focused to a proven SPI methodology. The methodology itself is fully customizable and allows organizations to make adjustments to the model where they feel it appropriate. Further, in order to demonstrate the usefulness, appropriateness, and practicality of the generic methodology, the Rosetta Stone IGSI-ISM to CMMI Instance mapping (RS-ICMMI) is developed using a generic set of business objectives developed by IBM Consulting Services which are then mapped to an established SPI methodology, namely the CMMI (Staged) model. Using the RS-ICMMI instance of the methodology, practitioners can readily determine which specific Process Areas should be undertaken to achieve specific business objectives. A validation phase was performed whereby both the methodology and the instance mapping were reviewed by experts.

The work presented in this thesis is entirely my own work. It has not been submitted previously to this or any other institute for this or any other academic award. Where use has been made of the work of other people, it has been acknowledged and referenced.

Signed: ____________________________________ Date: _______________

Fionbarr McLoughlin

To my beloved parents Evelayn (1942 – 1996) and Clement (1944 – 1995) McLoughlin

To Eimear, Niamh, Aisling, and Pierce

Thank you for your constant love, patience, and support

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Without the help and support of my parents, Evelayn and Clement McLoughlin, I honestly don't know where I'd be or what I'd be doing now. There were many bright people who grew up with me in Southill who never had the opportunities that I received from my parents. My Dad taught me that there's a difference between being smart and being educated. Please God, I'll always remember that.

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List of Acronyms

ATE	Automatic Test Equipment
BPI	Business Process Improvement
BPR	Business Process Re-engineering
CMM	Capability Maturity Model
CMMI	Capability Maturity Model Integrated
CMU	Carnegie Mellon University
COBIT	Control Objectives for Information and Related Technology
COCOMO	COnstructive COst MOdel
COQ	Cost Of Quality
CPI	Cost Performance Index
DD	Defect Density
DERA	Defence Evaluation Research Agency
DOD	(US) Department of Defense
GG	Generic Goal (CMMI-SW Staged 1.1)
GQM	Goal-Question-Metric
ICT	Information Communications Technology
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IGSI-ISM	IBM Global Services India - Interpretive Structural Modelling
IID	Iterative and Incremental Development
IRR	Internal Rate of Return
IS	Information Systems
ISD	Integrated Systems Development
ISO	International Standards Organization
ISACA	Information Systems Audit and Control Association
IT	Information Technology
ITGI	Information Technology Governance Institute

ITIL	Information Technology Infrastructure Library
ISO 12207	Software Process Lifecycle model
JTC1/SC7/WG10	Joint Technical Committee 1, Sub-committee 7, Working Group 10
KBPI	Knowledge-based Business Process Improvement
KPA	Key Process Area (CMM)
KSLOC	Source Lines of Code in Thousands (Kilo)
MIS	Management Information Systems
NASA	National Aeronautics and Space Administration
NGO	Non-Government Organizations
NPV	Net Present Value
NQSE	National Software Quality Experiment
OECD	Organization for Economic Coordination and Development
OGC	Office of Government Commerce
PA	Process Area (CMMI-SW Staged 1.1)
PAM	Process Assessment Model
PMAT	Process Maturity
PMBOK	Project Management Book Of Knowledge
PMI	Project Management Institute
PMO	Project Management Office
PRINCE2	PRojects IN Controlled Environments
PRM	Process Reference Model
QA	Quality Assurance
ROI	Return On Investment
RS-ICMMI	Rosetta Stone IGSI-ISM to CMMI Instance mapping
SEI	Software Engineering Institute
SEL	Software Engineering Laboratory (NASA)
SG	Specific Goal (CMMI-SW Staged 1.1)
SLA	Service Level Agreement
SLCM	Software Life Cycle Model

SME	Small and Medium Enterprises
SP	Specific Practice (CMMI-SW Staged 1.1)
SPA	Software Process Assessment
SPI	Software Process Improvement; Schedule Performance Index
SPICE	Software Process Improvement and Capability dEtermination
TPS	Test Program Set
UAT	User Acceptance Testing
USDOD	United States Department of Defence

1 Introduction

1.1 Background

Organizations do not exist in a vacuum. Every organization has certain objectives which it is chartered to achieve, depending on the type of organization. Some organizations are for-profit organizations which concentrate on achieving profits; some organizations are public service organizations which provide services to the public; yet others are chartered with furthering research and development activities. What they all have in common is that they want to achieve their relative organizational objectives as efficiently as possible, using the minimum of resources to maximum effect.

A significant amount of capital expenditure and operating expenses are spent on hardware, software, and technical support. In fact, according to the Organization for Economic Co-Operation and Development (2006), total worldwide spending on ICT[1] was expected to reach $2.964 trillion in 2005, the last year for which the OECD has published estimates. Given the massive amount of spending involved, anything which can shave even a few percentage points off costs could potentially free up a large amount of capital that could be used in either other areas of an organization or could be re-invested in further software development.

As disciplines, software engineering and information technology are relatively new and are maturing rapidly. Part of this maturity process has involved, and continues to involve, establishing best practices in the various domains that constitute the area. As we can see from Figure 1-1, various standards have emerged for the various domains and sub-domains within Software Engineering, Software Development and IT. From a management perspective, for example, we have the IT Governance Institute's (ITGI) Control Objectives for Information and Related Technology (COBIT®) standard (ISACA 2007) which is related to IT Governance; the Project Management Institute's (PMI) standard for Project Management as described in the Project Management Book of Knowledge (PMI 2004); the Office of Government Commerce's (OGC) PRINCE2 standard for

[1] In 1998, the OECD countries reached agreement on an industry-based definition of the ICT sector based on Revision 3 of the International Standard Industrial Classification (ISIC Rev. 3). The principles underlying the definition are the following: for manufacturing industries, the products of a candidate industry must be intended to fulfill the function of information processing and communication including transmission and display, must use electronic processing to detect, measure and/or record physical phenomena or control a physical process; for services industries, the products of a candidate industry must be intended to enable the function of information processing and communication by electronic means (OECD (2008). OECD.Stat Database, OECD.

Project Management as described in (OGC 2005); and the OGC's IT Infrastructure Library (ITIL) standard as defined in (OGC 2007b; 2007a).

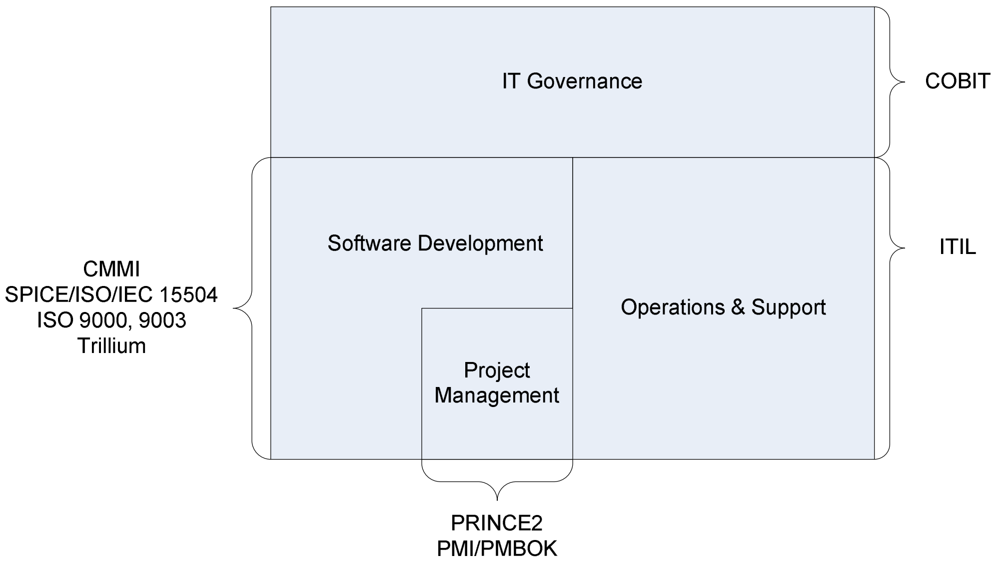

Figure 1-1: Software and System Domain standards

From a Software Process Improvement (SPI) perspective, there are several competing and, in some cases, complementary standards such as the Software Engineering Institute's CMMI for Development version 1.2 (SEI 2006); the International Standards Organization's (ISO) 15504 (ISO 2003), formerly known as SPICE; the Trillium Model (Coallier 1994; April and Coallier 1995), an assessment model that aims to benchmark a software supplier's product development and support capability which was developed originally in 1991 by Bell Canada; and the ISO's 9000-3 standard (ISO 1994) and the ISO 9001:2000 standard (ISO 2000) , a process-driven approach to define, establish and maintain software quality within an organization that will allow organizations to meet their business objectives (Hailey 2001).

All these initiatives aim to improve an organization's systems capabilities but they all aim to do so from an IT perspective. There are few, if any, methodologies which approach systems improvement from a business goals and objectives perspective. The Rosetta Stone Methodology, developed and evaluated during this research, consists of a methodology, a meta-model, and a concrete instance of that meta-model which allows businesses to undertake business- and organizational-driven goals and objectives.

1.2 Research Objectives

There are currently several major Software Process Improvement (SPI) methodologies being actively used in organizations worldwide. While these methodologies will continue to mature and evolve over time, one thing they all have in common is that they are IT-centric. The focus of these methodologies is the implementation of specific IT and software engineering practices in order to gain benefits. They do not focus on satisfying a business objective by implementing specific IT practices. As we shall see in Chapter 2, there is quite a deal of literature available to support the hypothesis that implementation of the various SPI methodologies will result in benefits to organizations. However, these benefits come about *as a result* of implementation of SPI i.e. SPI, which is IT-centric, drives the benefits. There is no ability within the established SPI methodologies to define what benefits/objectives an organization would like to achieve and use *business-centric* objectives to drive what particular SPI initiatives should be undertaken.

The purpose of this research is twofold. Firstly, a methodology has been developed which allows practitioners to map arbitrary business benefits models to arbitrary SPI models or methodologies. Secondly, a mapping of business-centric benefits to CMMI (Staged) has been developed which allows practitioners to target specific business benefits through the implementation of various Process Areas (PAs). In order for the methodology and mapping instance to be successful:

- they must take into account the wide variety of organizations that exist as well as their overall goals and objectives. Examples of these various types of organizations include for-profit organizations such as Goldman Sachs and General Electric, public service organizations such as local authorities, government departments, and research organizations such as NASA and various universities
- they should be able to re-use existing SPI methodologies such as CMM/CMMI, Trillium, ISO 9000/9001, and ISO/IEC 15504
- they should be directly usable by practitioners within the organizations concerned – organizations should not have to rely unnecessarily on outside experts to implement the methods defined within the overall methodology.

Both the generic methodology and the concrete mapping developed during this research were evaluated through interviews which are presented in chapters 5 and 6.

1.3 Outline of Dissertation Structure

The dissertation is structured as follows:

- **Chapter 1: Introduction**. Chapter 1 provides a context for this research. It explains why there is a need for the Rosetta Stone Methodology and why it is an appropriate approach to solving issues that many organizations face on a daily basis. In addition, Chapter 1 outlines the remaining chapters.
- **Chapter 2: Literature Review.** Chapter 2 provides a high level review of CMMI and ISO/IEC 15504 as well as a high-level comparison and a genealogy of their development. It also provides a literature review of the benefits of implementing various SPI methodologies with a specific emphasis on CMM and CMMI as these two models are the basis for the specific implementation of the Rosetta Stone implementation detailed in Chapter 4. In addition, it discusses Business Process Improvement (BPI) and how it links into SPI.
- **Chapter 3: Research Methodology.** Chapter 3 details the research process and research methodology that is used in this research work. The chapter provides specific information on how the model was developed and evaluated and what is the academic basis for the research methods used.
- **Chapter 4: The Rosetta Stone Objective-Driven SPI Methodology.** The generic Rosetta Stone Methodology is introduced which allows organizations to map organization- and business-driven objectives to various SPI methodologies. Using the generic Rosetta Stone Methodology, a specific implementation is explored using a generic, for-profit objectives model obtained from IBM Global Services, India (Goyal et al. 2001) and the CMMI Staged Representation (CMMI Product Team 2002).
- **Chapter 5: Rosetta Stone Methodology Validation Process.** In order to evaluate and validate the model, interviews were conducted with various practitioners, authors, and academics. Chapter 5 contains the results of these interviews.
- **Chapter 6: RS-ICMMI Validation Process.** An implementation of the RSM was created which consists of all the mappings from the IBM Global Services (India) Interpretive Structural Modelling (IGSI-ISM) benefits model to CMMI (Staged). These individual mappings were discussed in-depth with various practitioners and academics for CMMI (Staged) Level 2 and the model and instance mapping were modified accordingly. The results of the interviews and the re-mapping are discussed in Chapter 6.
- **Chapter 7: Summary and Conclusions.** Chapter 7 brings together the various strands of this research and draws conclusions, lessons learnt and scope for future research.

2 Literature Review

2.1 Introduction

Over the years, software and systems development methodologies have evolved to enable the development of larger scale and ever more complex solutions to real-world problems. Significant advances in hardware design have given software engineers enough raw computing power to them to allow them to create solutions for more and more complex and larger problem domains. Unfortunately, however, improvements in software design and development have not kept pace with these advances in hardware. Brooks (1995) states that "larger-scale programming over the past decade has been such a tar pit, and many great and powerful beasts have thrashed violently in it."

The good news, however, is that advances have been made and, while there are still quite a few horror stories reported in the press, we now appear to be more capable of developing more large-scale, complex systems than previously. To get to where we are now, however, has taken a lot of hard work and the gradual evolution of development processes. Initially, the focus of improvement was on general engineering solutions such as Fagan's work on Software Inspections (Fagan 1986) and Structured Programming (Jackson 1975; Djikstra 1979) but later on focus shifted to various, specialized Software Process Improvement (SPI) and Project Management methodologies. In addition to the reported progress on SPI, a great deal of research has been undertaken on Business Process Improvement (BPI). IT is seen as an integral part of this and there is a growing body of work which seeks to integrate both BPI and SPI.

This first part of this chapter focuses in providing a background on software development lifecycles in general as well as a review of two of the leading SPI/SPA models. In addition, this chapter also reports on the demonstrated benefits of software engineering improvement techniques in general as well as of SPI, BPI, and the integration of both SPI and BPI.

2.2 Definitions

Before proceeding further it is important to provide appropriate definitions for the subjects being discussed in this chapter. The basis for the life cycle definitions in this thesis is the IEEE/EIA 12207.0 standard (1996), which provides a framework for all software lifecycle processes. According to the standard, individual projects may be tailored and must be mapped onto a Software Life Cycle Model (SLCM) (IEEE/EIA 1998; Schmidt 2000). Examples of the SLCM include the Waterfall Model and the Spiral Model, both of which are software development models and which shall be discussed in the next section. The definition of the Software Life Cycle is quite broad and, according to the standard, may include items not specific to the development process such as operational support and acquisition of services so we therefore distinguish between the Software Development Life Cycle and the Software Life Cycle.

Sommerville (2004) defines the software process as a structured set of activities required to *develop* a software system, including at least the processes of specification, design, validation, and evolution. According to Paulk et al. (1995) the software process "can be defined as a set of activities, methods, practices, and transformations that people employ to *develop and maintain* software and the associated products." While implied in Sommerville's definition, Boehm (1998) specifically includes the notion of order to the definition of the software process in that "the primary functions of a software process model are to determine the order of the stages involved in software *development and evolution* and to establish the transition criteria for progressing from one stage to the next." According to these definitions, therefore, the terms "software process" and "software development process" may be regarded as being synonymous. For the purposes of this thesis we treat the terms "software process", "software development process" and "software development life cycle" as being synonymous while the "software life cycle" encompasses all phases, including the operational phase, of software.

The work presented in this thesis is the Rosetta Stone Methodology and is composed of 2 parts – the Rosetta Stone Methodology (RSM) which is the methodology used to create an implementation instance of the Rosetta Stone meta-model and the Rosetta Stone Implementation instance for CMMI (RS-ICMMI) which is an implementation instance of the RSM based on the IGSI-ISM benefits model and the CMMI (Staged) SPI model.

2.3 Software Development Life Cycles

Probably the earliest software development process model discussed in the literature is discussed in Davis et al. (1988) and was the code-and-fix model whereby development consisted of two steps:

1. Write program code
2. Fix any issues or bugs in the code.

While this approach was fine for very small development efforts, it had several inherent weaknesses in that, as there was no design phase, the code became brittle and inflexible over time and, as a result, expensive to maintain. In addition, again as a result of the lack of a design phase, it was not well suited to large-scale system development.

In the 1950s, as computers became more mainstream, the scope and complexity of potential applications for this technology increased and the weaknesses of the code-and-fix model became more apparent. The next recognized leap forward in software process development came about as a result of experiences in the SAGE (Semi-Automated Ground Environment) air-defence system. In his paper, Pennington (1956) describes the Stagewise model where software is developed in successive stages - operational plan, machine/operational specifications, program specifications, coding specifications, coding, parameter testing (specifications), assembly testing (specifications), shakedown, and system evaluation. Unfortunately in this model there are no feedback loops to previous stages to fix/change issues at later stages.

The next evolution in software development process is the familiar Waterfall Model (Royce 1970) where the software development process consists of a set of discrete activities/stages, performed in a non-overlapping manner. Pure Waterfall consists of the following implementation phases (see also Figure 2-1):

- System Requirements
- Software Requirements
- Analysis
- Program Design
- Coding
- Testing
- Operations.

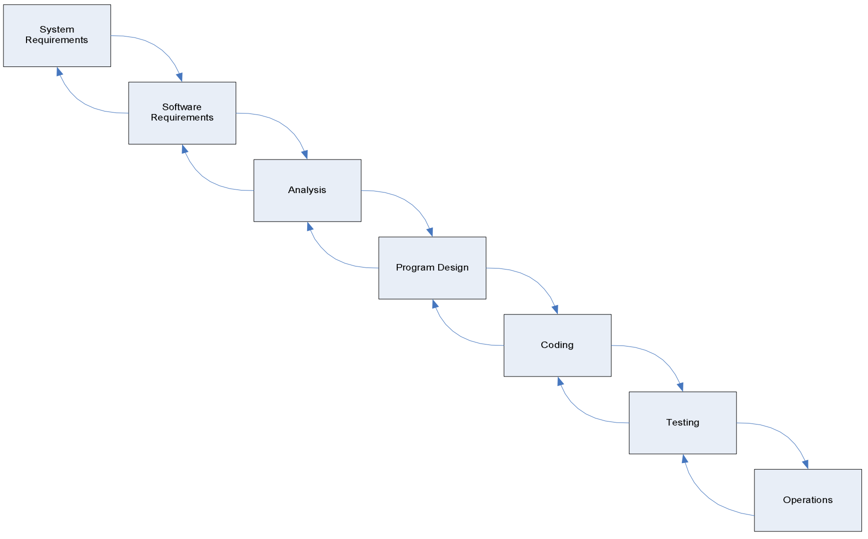

Figure 2-1: Waterfall Lifecycle (Royce, 1970)

The big difference between this model and the Stagewise model is that Royce provides feedback loops to previous stages, allowing changes to be made to previously developed work. However, there are still some challenges with the Waterfall model in that there is an emphasis of having fully completed requirements and design documents before proceeding farther down the waterfall. Clearly this is a deficiency as real-life rarely works like this. In fact, according to Parnas and Clements (1986), there are several other reasons why the waterfall model is not an accurate representation of a real-life project life cycle. Those reasons include the fact that human beings are unable to fully understand all the relevant details about a complex system; requirements change for external reasons that are beyond the control of the project team; and project teams are sometimes encouraged to use sub-optimal tools or share code with other projects. In real-life, it is more likely that a project will evolve over time and thus design and development is much more iterative than it would appear in the Waterfall model. The Spiral Model (Boehm 1998) addresses this issue by allowing multiple cycles of:

- Determination of objectives, alternatives, and constraints
- Evaluation of alternatives, identification and resolution of risks
- Development and verification of next-level product
- Planning for next phases.

where each cycle is an elaboration of previous cycles (see Figure 2-2).

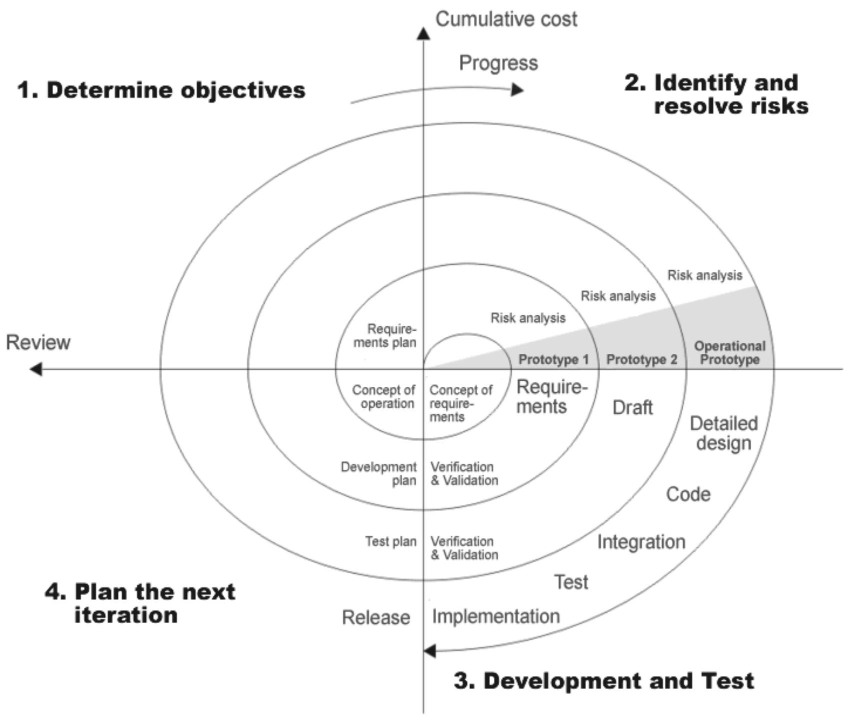

Figure 2-2: Spiral Lifecycle (Boehm, 1998)

2.4 Software Process Improvement Models

Software Process Improvement (SPI) has been defined as "making better tools, on time and within budget" (Fantina 2005). For the purposes of this work, I define SPI as any change to the software development process which has a positive effect on the time, quality, or cost of software development.

Unfortunately even within the software cognoscenti, people get confused about the difference between a model and a methodology. A model, according to the Concise Oxford English Dictionary (2008), is "a simplified mathematical description of a system or process, used to assist calculations and predictions"; a methodology is "a system of methods used in a particular field"; and a standard is "something used as a measure, norm, or model in comparative evaluations."

Several widely-known Software Process Improvement standards currently exist. Sheard (1997) identifies 7 important frameworks and identifies some major focus areas of each (see Table 2-1). Since Sheard's paper in 1997, the SEI has sunsetted CMM, replacing it with CMMI, and the ISO/IEC 15504 assessment framework (formerly known as SPICE) has emerged as a growing force in several domains such as the automotive domain (Automotive SPICE) the banking domain (Banking SPICE), and the medical domain (Medi SPICE). The Trillium model, based on personal correspondence with Francois Coallier (2003), has not been updated since 1996 and there are no further plans to update it. As a result of all this, we shall concentrate on the 2 widely used SPI/SPA models/frameworks in use today – CMMI and ISO/IEC 15504.

Framework	**Major Focus**
CMM	Software Process
SE-CMM	Software Engineering Process
IPD-CMM	Process
ISO 9000	Quality Process
SDCE	Process, Capacity, Technology
Software Lifecycle Standards	Management Process
Trillium	Software Process

Table 2-1: Characteristics of Seven frameworks (Sheard, 1997)

2.5 CMMI - the Capability Maturity Model Integrated

2.5.1 The Capability Maturity Model Integration - CMMI

Carnegie-Melon University's (CMU) Software Engineering Institute (SEI) and the MITRE Corporation, in response to a request from the US federal government, began developing a process maturity framework that would help organizations improve their software process. The genesis of this framework was based on previous work by Humphrey (1987; 1988; 1989) and was published as *The Capability Maturity Model for Software* (Paulk et al. 1993). The initial release of the CMM, Version 1.0, was released for review by the software community during 1991 and 1992. Further refinements were made and Version 1.1 was published in (Paulk et al. 1993).

However, the CMM model was not without its criticisms. According to Ahern et al. (2001), one of the major disadvantages of CMM was that there was no integration between the CMM for Software (CMM-SW), the CMM for Systems Engineering (CMM-SE), and the Integrated Product Development CMM (IPD-CMM) models. In addition, Royce (2002) reports that one of the key issues he encountered with CMM is that the Key Process Areas (KPAs) mostly focus on activities and processes based on the traditional Waterfall process model. He also noted that there was no emphasis on the architecture/design process, the assessment process, or the deployment process. In response to these criticisms, the Capability Maturity Model Integration (CMMI) addresses these issues (Ahern et al. 2001; Konrad and Shrum 2001; Chrissis et al. 2003). One other major issue that CMMI addresses is to be "consistent and compatible with ISO/IEC 15504" (Chrissis et al. 2003). Subsequent to the 1.1 release of CMMI, version 1.2 was released in August 2006 and there are further plans in hand for version 1.3.

CMMI exists in 2 representations - the "continuous" approach like ISO/IEC 15504 where the focus is on specific processes and the "staged" approach where organizations undertaking CMM at Level 1 and work up to Level 5. In addition to the Staged and Continuous representations, the underlying model has changed dramatically (SEI 2002d; 2002c) and there are now 25 CMMI Process Areas compared to 18 CMM Key Process Areas. The top-level object in both models is the *Process Area* (PA) (see Figure 2-3). There are 25 distinct PAs within CMMI and each area covers a distinct set of practices. Each Process Area has a *Purpose Statement* that describes the purpose of the PA, a set of *Introductory Notes* that describes the major concepts within the PA, and a list of other *Related Process Areas*. A PA is composed of a set of *Specific Goals* that are unique to that PA. On the opposite end of the spectrum, a PA has a set of *Generic Goals*. Unlike Specific Goals, however, Generic Goals may be applicable to several PAs and are responsible for institutionalizing processes. *Specific Practices* are descriptions of activities that contribute to Specific Goals, while *Generic Practices* are those activities that contribute to Generic Goals. While CMMI provides the definition of what components an organization must achieve to satisfy a Process Area, it does not describe how it should be implemented. As a result, there is a clear distinction between a process model or class - in CMMI terms, a Process Area - and a Process Instance, which is a concrete implementation of a process model. For example, the CMMI Configuration Management process area talks of baselines and managing baselines, it does not provide guidance on how to implement this – for example, for software development artefacts, tools such as Visual Source Safe or the Concurrent Versioning System (CVS) would typically be used.

CMMI Model Architecture

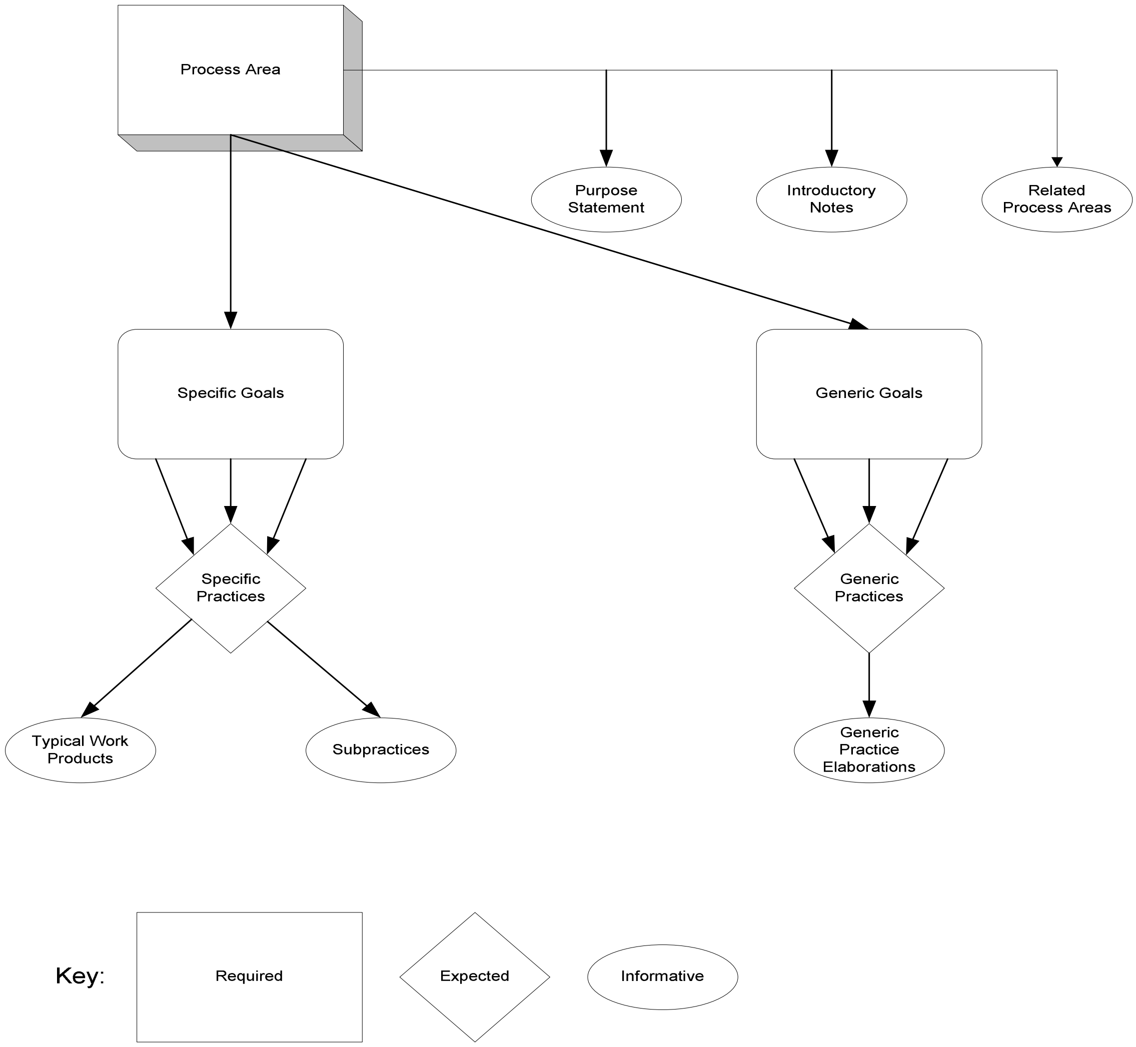

Figure 2-3: CMMI Model Structure (Chrissis et al., 2003)

2.5.2 CMMI Staged versus Continuous Representations

According to Chrissis et al. (2003), both the Staged and Continuous representations are designed to offer essentially the same results – in fact, more than 80% of both representations are the same. How then does one decide which representation to use? Several factors may affect this decision:

- Legacy – does the organization currently employ the CMM model?
- Business Factors – do the business goals and objectives of the organization allow the organization the time to go through the various levels of the Staged Representation or is there a compelling reason to concentrate on one (or several) areas before concentrating on the various other Process Areas?
- Cultural – does the organization's culture lend itself to one representation over the other?

In addition to the above criteria, Ahern et al. (2001) cite several reasons for choosing the Staged representation over the Continuous representation and vice versa (see Table 2-2).

Staged	Continuous
• Ability to manage the process across the organization • Good communication about the process amongst the employees • Improved accuracy of project estimates • Improved cost and quality control • Use of measurable data to guide problem analysis and improvement efforts	• A structure that is more easily compatible with ISO/IEC 15504 • An approach that more easily facilitates the addition of new process areas with minimal effects on the existing model structure

Table 2-2: Staged and Continuous relative advantages (Ahern et al, 2001)

At a high level, the representations differ in several ways:

- In the Continuous representation, PAs are organized by process area categories, while in the Staged representation, PAs are organized by Maturity Level
- In the Continuous representation, improvement is measured by Capability Levels, while Maturity Levels are used in the Staged representation

- Capability Levels are used to organize generic practices in the Continuous representation, while Common Features are used in the Staged representation

2.5.3 CMMI – Staged Representation

The Staged Representation still uses the concept of Maturity Levels as used in the original CMM. As there are now 25 different PAs vs. the 18 there were in CMM, the mapping has changed (see Table 2-3).

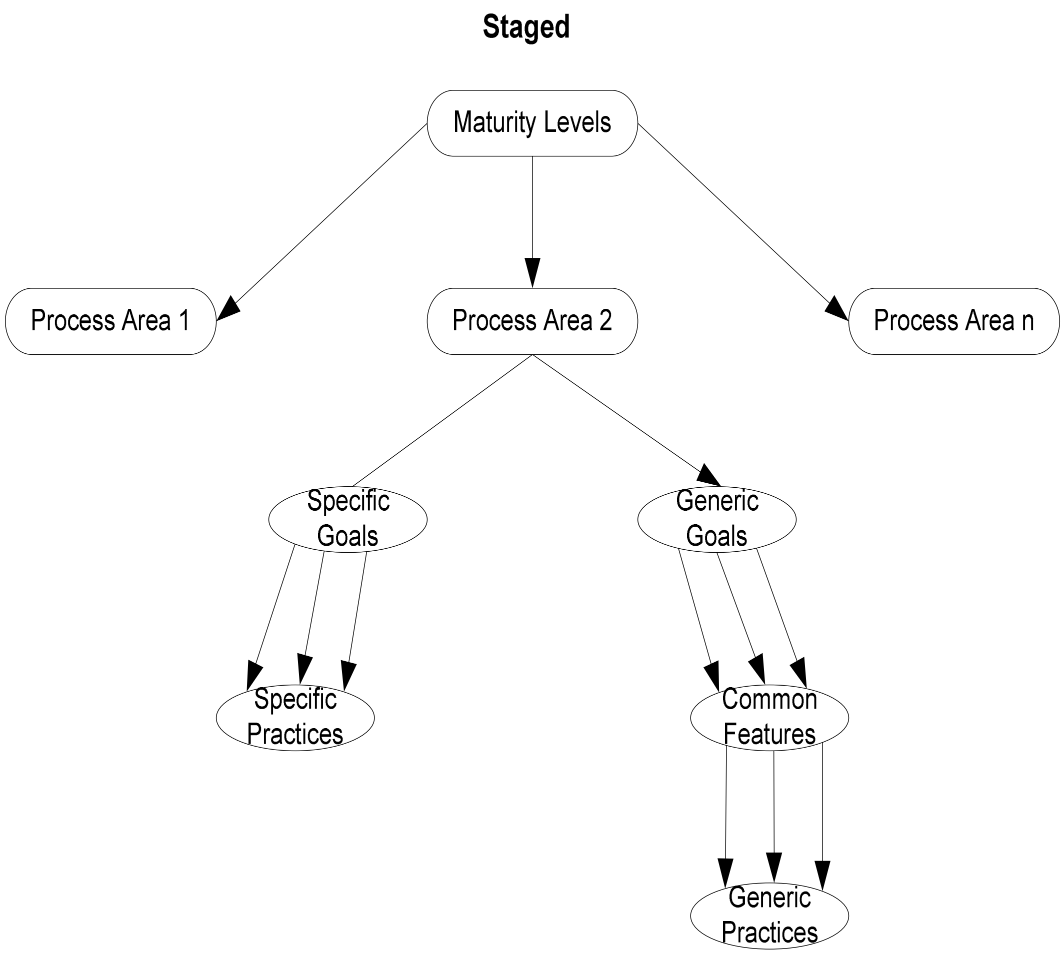

Figure 2-4: CMMI Staged Representation

Maturity Level	Process Areas
Level 1: Initial	NA
Level 2: Managed	Configuration Management Measurement & Analysis Project Monitoring & Control Project Planning Process & Product Quality Assurance Requirements Management Supplier Agreement Management
Level 3: Defined	Decision Analysis & Resolution Integrated Project Management Integrated Supplier Management Integrated Teaming Organizational Environment for Integration Organizational Process Definition Organizational Process Focus Organizational Training Product Integration Requirements Development Risk Management Technical Solution Validation Verification
Level 4: Quantitatively Managed	Organizational Process Performance Quantitative Project Management
Level 5: Optimizing	Causal Analysis & Resolution Organizational Integration & Deployment

Table 2-3: CMMI Staged PA to Level mapping

2.5.4 CMMI – Continuous Representation

While the Staged Representation utilizes the concept of Maturity Levels, the Continuous Representation utilizes the concept of *Capability Levels*. A Capability Level consists of a distinct set of related *Specific* and *Generic Practices* that, combined, add a significant capability to an organization's abilities for a Process Area. There are six distinct Capability Levels (see Table 2-4).

Capability Level	Description
Level 0: Incomplete	One of more of the specific goals and none of the generic goals are satisfied
Level 1: Performed	The specific goals for the PA are satisfied
Level 2: Managed	Level 1 is satisfied and basic infrastructure is in place to support the PA
Level 3: Defined	Level 2 is satisfied and the process is tailored from the organization's defined processes
Level 4: Quantitatively Managed	Level 3 is satisfied and statistical control is used to analyze the PA
Level 5: Optimizing	Level 4 is satisfied and processes evolve using inputs from Level 4

Table 2-4: CMMI Capability Levels

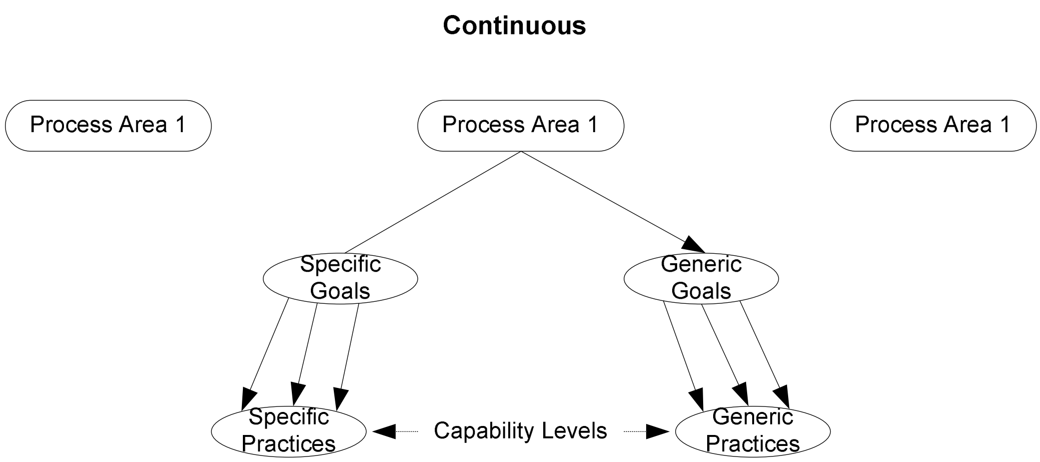

Figure 2-5: CMMI Continuous Representation

As mentioned, the staged approach has been kept in order to allow organizations to retain their investment in CMM. However, as CMMI continues to integrate more and more closely with ISO/IEC 15504, it would not be unreasonable to assume that the continuous approach will continue to gain more popularity.

2.6 ISO/IEC 15504

2.6.1 Overview of ISO/IEC 15504

The purpose of ISO/IEC 15504 (previously known as SPICE - *S*oftware *P*rocess *I*mprovement *C*apability d*E*termination) is to provide a framework for the assessment of software processes. According to (International Standards Organization 2004), Process Assessment has 2 principle contexts for its use (see Figure 2-6):

1. Process Improvement. Process assessment provides the means of characterizing the current practices within an organization in terms of the capabilities of selected processes. Analysis of the capability of those processes identifies strengths and risks inherent in them and provides drivers for prioritizing improvements to them.
2. Process Capability Determination. Process capability determination is concerned with analysing the proposed capability of selected processes against a target process capability profile.

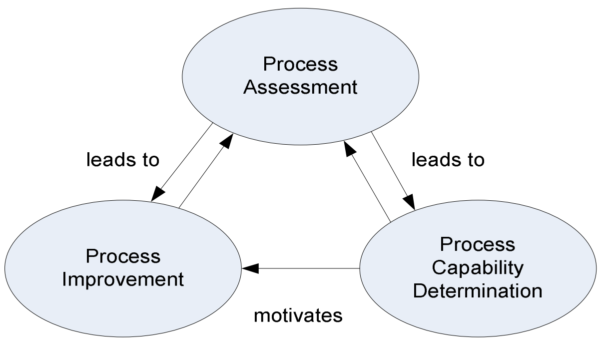

Figure 2-6: ISO/IEC 15504 Process Assessment Relationship (ISO/IEC 15504-1)

Under ISO/IEC 15504, a Process Reference Model (PRM) is measured against a measurement framework to produce a Process Assessment Model (PAM). This is graphically illustrated in Figure 2-7. PRMs provide the mechanism whereby defined PAMs are related to the measurement framework and are defined in (International Standards Organization 2003). A PRM is defined externally to the ISO/IEC 15504 standard but needs to adhere to certain requirements which are laid out in the ISO/IEC 15504 standard in order to be conformant with the standard. In addition to the requirements in order to be compliant with an ISO/IEC 15504 PRM, ISO/IEC 15504-5 (International Standards Organization 2006) provides an exemplar Process Reference Model. Under the measurement framework in (International Standards Organization 2003), a process capability is defined on a six point ordinal scale that enables capability to be assessed from the bottom of the scale, Incomplete, through to the top end of the scale, Optimizing (see Figure 2-8). The scale represents increasing capability of the implemented process, from not achieving the process purpose through to meeting current and projected business goals.

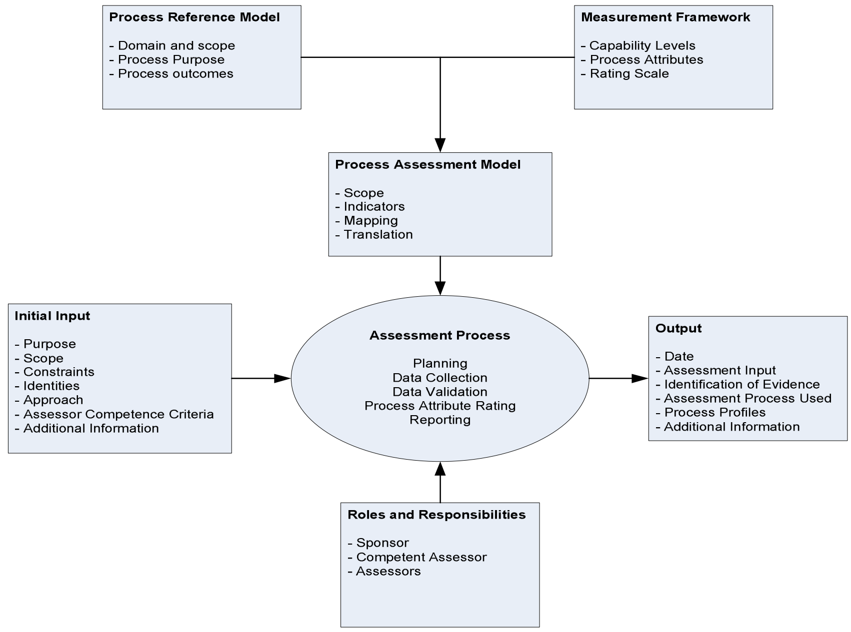

Figure 2-7: ISO/IEC 15504 Assessment Process (ISO/IEC 15504-1)

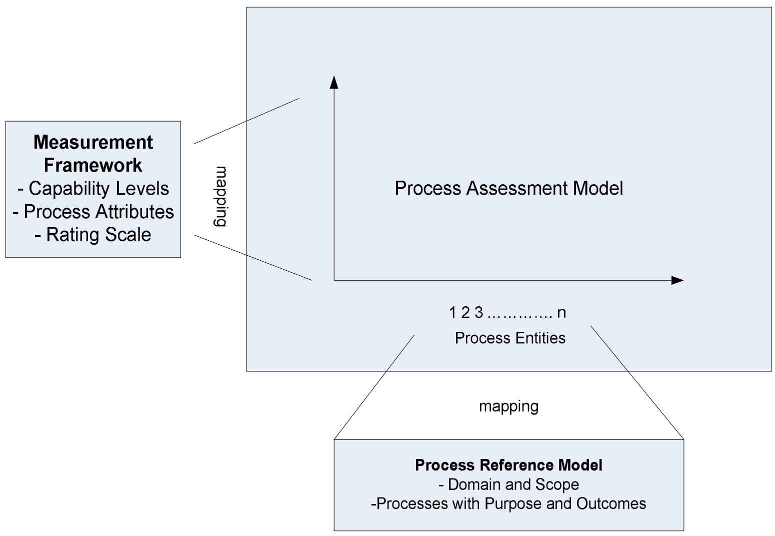

Figure 2-8: ISO/IEC 15504 Process Model Relationships (ISO/IEC 15504-1)

2.7 Analysis of ISO/IEC 15504 and CMMI

2.7.1 Relationships and History

Many of the current models have been influenced by previous models. Table 2-5 contains a brief chronology of the models which have been discussed (Tantara Consulting Services Inc. 2001) and which has been slightly modified by this researcher. In addition to the chronology of the various models, many of the models have taken the best features of existing models and have incorporated them into their own. Figure 2-9 shows the relationships between the various models (Tantara Consulting Services Inc. 2001).

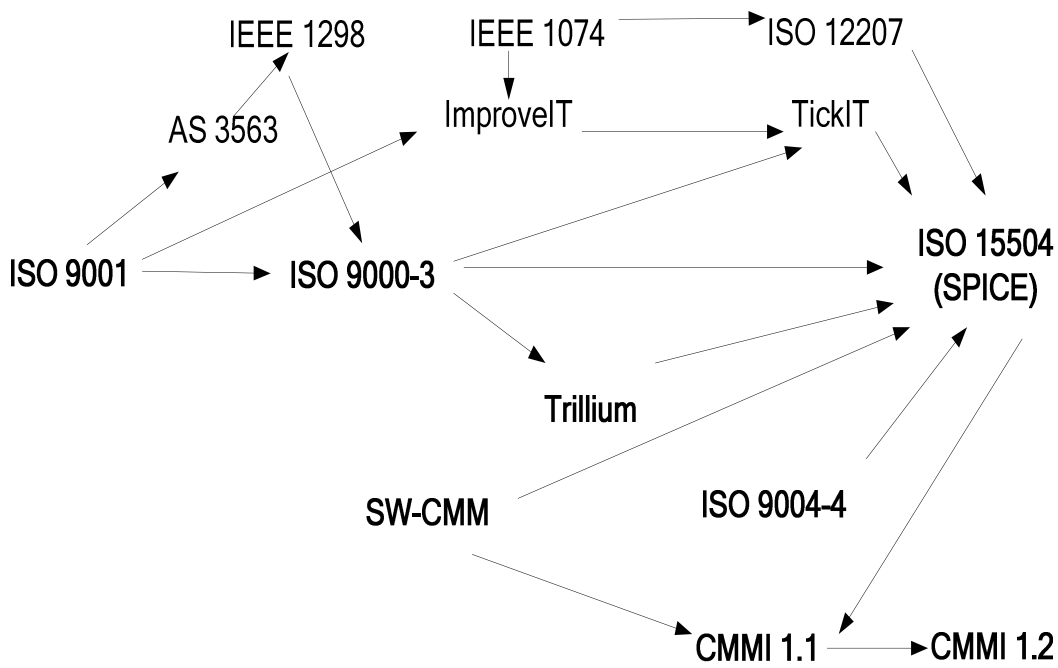

Figure 2-9: Relationships between Models (Tantara Consulting, 2001)

Year	History
2006	SEI CMMI for Development 1.2 released
2000	ISO 9000:2000 released SEI CMMI v1.02 released
1998	ISO/IEC 15504 (SPICE) released to public as "type 2" Technical Reports TickIT v4.0 released
1997	ISO 9000-3 released SEI halts SW-CMM versions in support of CMMI
1996	IEEE/EIA 12207 released
1995	IEEE/EIA 12207 released (initial release) ISO/IEC 15504 (SPICE) initial draft released
1994	ISO 9001 re-released Trillium v3.0 released
1993	SEI CMM-SW v1.1 released
1992	IEEE adopts the Australian AS 3563 as IEEE 1298
1991	IEEE 1074 released ImproveIT v1.0 released ISO 9000-3 initial released SEI SW-CMM v1.0 released Trillium v1.0 released
1988	AS 3563 (Software Quality Management System) standard released
1987	ISO 9001 initial release NIST/MBNQA: 1st Malcolm Baldridge National Quality Award (USA) SEI-87-TR-24 (SW-CMM questionnaire) released

Table 2-5: Model Chronology (Tantara Consulting Inc., 2001)

2.7.2 Comparison of Models

ISO/IEC 15504 and CMMI are the two most recent SPI/SPA models. They have been built on the experiences of the many previous SPI/SPA models that have gone before them (see Figure 2-9 for details). The main difference between them, however, is that ISO/IEC 15504 is a standard for process assessment, while CMMI is a Software Process Improvement model.

According to Rout (1998), a key outcome of the ISO/IEC 15504 standard "must be to encourage harmonization of existing schemes." Rout (2003) states that ISO/IEC 15504 identifies two classes of process model – Process Reference Models (PRM) and Process Assessment Models (PAM). The purpose of a PRM is "to provide descriptions of process entities to be evaluated – to define what is being measured" while the purpose of a PRM is to support the conduct of an assessment." More specifically, ISO/IEC 15504-2 (2003) specifies that a conformant PAM shall be based upon a suitable reference source of process definitions (PRM). ISO/IEC 15504 may be seen therefore as being a meta-model for process assessment whereby concrete PRMs are used in practice. Van Loon (2007) states that, in order to ensure consistency and repeatability of assessments, a conformant PAM shall contain:

- A definition of its purpose, scope, elements, and indicators
- A mechanism for consistent expression of results
- The mapping to the ISE/IEC 15504 Measurement Framework and the specified Process Reference Models.

Given the above criteria, is CMMI a conformant PAM? Rout and Tuffley (2007) undertook an analysis conformance of CMMI (Continuous) to ISO/IEC 15504 and identified several significant issues from a PAM perspective. From a PRM perspective, Rout and Tuffley were confident that "with a few exceptions, a profile of acceptable scope should be derivable" but "the analysis of the Capability Dimension implies significant problems in evaluating capabilities beyond Level 2." This contention is also supported by a pilot appraisal by Kitson et al. (2006). Pino et al (2009) undertook a similar analysis between CMMI-DEV (Staged) and ISO/IEC 15504. Their conclusion is that there is either strong or large coverage for 15 out of the 22 CMMI-DEV PAs, partial coverage for 5 PAs, and weak coverage for 2 PAs and that, with regard to maturity levels, the processes of a maturity level of ISO/IEC 15504 cover several process areas that belong to different maturity levels of CMMI – there is no one-to-one relationship between ISO/IEC 15504 and CMMI maturity levels.

2.7.3 The Future of CMMI and ISO/IEC 15504

So what does the future hold for SPI/SPA? It would appear that the two models that are in best position to survive are the CMMI and ISO/IEC 15504 models. CMM is the most widely used model in the United States and, probably, in the world right now. The SEI is spending considerable resources promoting their new CMMI model and it seems poised to benefit from the current CMM and CMMI 1.2 user-bases. In addition, the SEI continues to make efforts to harmonize CMMI with ISO/IEC 15504. ISO/IEC 15504 is constantly being worked on and expanded. For example, ISO/IEC 15504 has now been extended to the automotive domain (Automotive SPICE), while the medical domain (Medi SPICE), and the banking domain (Banking SPICE) are under development.

Given the expressed desire of both the CMMI and ISO/IEC 15504 teams for harmonization, will harmonization be achieved? However, several obstacles will have to be overcome to make the dream a reality:

- CMM and CMMI are looked upon as being specifically American in nature, especially given the fact that the SEI is directly supported by the US Department of Defense
- CMM and CMMI have a large installed-base, making it difficult for major changes to CMMI to be made.

In the short run therefore, we can expect both models to co-exist and, perhaps, in the longer term work may be done to either combine both models or, at the very least, to make CMMI fully compliant with ISO/IEC 15504 and ISO/IEC 12207:2008 (2008) – by modifying either CMMI or changing ISO/IEC 15504 or ISO/IEC 12207.

2.8 Agile Software Development and SPI

As was pointed out in Section 2.3, the Waterfall model is not an accurate reflection of either real life or of how projects are actually developed. Despite the fact that it appears that the Waterfall model predates the Spiral model, Larman and Basili (2003) make the case that Iterative and Incremental Development (IID) has been in existence for long before the Waterfall model. According to Williams and Cockburn (2003), "beginning in the mid-1990s, many found [the] initial requirements documentation step frustrating and, perhaps, impossible." As a result of this and other issues, several methodologies were developed that allowed developers to embrace change rather than reject it. In 2001, 17 developers and authors came together to discuss their experiences and came up with the "Manifesto for Agile Software Development" (www.agilemanifesto.org). The manifesto values:

- Individuals and interactions over processes and tools
- Working software over comprehensive documentation
- Customer collaboration over contract negotiation
- Responding to change over following a plan.

Based on the manifesto, Agile software development methods promote development iterations, teamwork, collaboration, and process adaptability throughout the lifecycle of the project. Typically, development is characterized by short "time boxes" where development activities are carried out within a precise period of time. If some required functionality for that release cannot be developed within the specified period, then it is left out rather than extending the development period. In short, the focus is on multiple, short iterations of development which allows the developers to be able to quickly react to changes or refinements in requirements.

While Agile methods appear to be quite successful at overcoming the issues experienced in the Waterfall model, how do they interact with SPI models and, specifically, CMMI? While at first glance it may appear that Agile and SPI/CMMI are orthogonal in their approaches, there is a growing body of evidence to the contrary and, in fact, some research seems to suggest that these methodologies are in many ways complementary. One of the common reasons suggested for using Agile is that it is a lean approach which uses fewer resources than other methods. This, in fact, is very much in line with the goal of CMMI – according to Glazer et al. (2008) "when viewed holistically, CMMI's ultimate goal (i.e. continuous process improvement) is to cause an organization to become less wasteful, leaner, and more in touch with actual development progress." Jakobsen and Johnson (2008) and Sutherland et al. (2007) detail their positive experiences from mixing Scrum (an Agile methodology) and CMMI:

- CMMI risk management proactively addresses possible impediments before they are experienced by the team
- CMMI quality planning specifies more accurately and efficiently the quality targets of projects and helps developers to a better interpretation of completion criteria and sprint goals
- CMMI ensures that a project is tracked as a whole, not just for the current sprint
- CMMI ensures that agile methods are institutionalized.

To further the assertion that CMMI and Agile are in fact complementary, Omran's research (2008) into Agile development methods and CMMI suggests that Small and Medium Enterprises (SMEs) can adopt Agile methodologies and CMMI to provide value to the enterprise. Microsoft have also implemented a combined Agile/CMMI approach (Anderson 2005) and by doing so have developed "a truly agile full life cycle process for all 5 levels in the CMMI model." DTE Energy (Baker 2005; 2006) have combined both Agile and CMMI and DTE "believes that Agile methods are an accelerator to process improvement when applied appropriately and meaningfully."

There is, however, one other dimension to take into account when discussing Agile and CMMI and that is size. According to Jones (2008), Agile methods tend to break projects down into smaller projects of about 100 – 250 function points. That withstanding, he asserts that Agile methodologies can improve productivity for projects up to about 1,500 function points. However, for larger projects in the range of 10,000 – 100,000 function points, formal control points such as change management, design, and code inspections are essential. In other words, there is a point at which Agile methods need to make way for more formality.

In summary, it appears that there is evidence to support the assertion that both Agile development methodologies and SPI in the form of CMMI are complementary. According to Jones (2008), however, there is a point where Agile can no longer be *fully* used in conjunction with CMMI and development must become more formal.

2.9 Costs and Benefits of SPI

2.9.1 Consistency and Limitations of Reported Benefits of SPI

There is a great variety of benefits attributed to SPI in the literature. However, before exploring the reported benefits, we must recognize that there are limitations and variations in how the results described in the literature are arrived at. El Emam and Madhavi (1996a), in their study on organizational maturity and quality, categorize existing literature in one of two categories – case studies or correlational studies. Case studies, where a single organization's experiences are described, suffer from selection bias in that organizations which have not shown improvement or have even regressed over time will be reluctant to publicize their results and that organizations which have not improved to a reasonable maturity will lack the data to qualify for case-study selection. Correlational studies, on the other hand, are useful for showing a general correlation between increased maturity and effectiveness. Ideally, in order to critically and objectively evaluate the benefits as described in the literature, the results should be consistently categorized, defined, and normalized. Categorization is required to ensure that we compare like benefits with like benefits; definition is required so that any assumptions or background information is clearly described up front; and normalization is required to be able to make an objective comparison of results across organizations of various sizes, industries, and maturity levels etc. Unfortunately, normalization and consistency in both reporting and real-life are in many cases not possible for many valid reasons. Zahran (1996) points out that "it seems that every organization follows its own approach to measuring the benefits of SPI since there is no common standard or models for performing cost-benefit justification of SPI." This lack of standardization is also reflected by Solon and Statz (2002) who discuss the difficulties of using benchmark SPI benefits in making business cases for the implementation of SPI. In addition, they also create a high level categorization of SPI benefits and summarize the possibilities of making benefits benchmarks (see Table 2-6), including noting where they believe there is the potential of making the benefit a benchmark benefit (the "Yes/No" column).

In order to illustrate these issues, 3 examples which highlight the implications of lack of normalization and consistent definition are discussed here. The first example is Defect Density (DD), which is one of the most commonly cited SPI benefits. Defect Density is typically defined as being a measure of the total number of defects in code in relation to the total number of lines of code. While this appears to be a concise and clear definition of DD, some aspects of the definition are open to interpretation. For example, what particular stage in the lifecycle does the metric refer to? Does it refer to production code, post-QA code or post-UAT code? In addition, there is a normalization issue as well - does a particular DD statistic published in the literature refer to Java Code or Assembler-level code? Clearly in order to be able to make a comparison between two different claims in the literature, more information that just the label "Defect Density" is required. The second example is Productivity – another widely attributed benefit of SPI. What precisely does productivity mean? Is a claim based on *project* productivity whereby it takes less time and resources to undertake a *project* as a whole or is productivity meant to define just coding productivity? Even if we are told that productivity is really project productivity, how do we compare like projects with like projects? Are they based on the same number of lines of code, the same number of developers or even the same technologies? As with DD, we need to be able to normalize common factors to be able to accurately and objectively compare benefits between one literature report and another. Finally, let us take a look at Return On Investment (ROI). ROI is a commonly used calculation (though not the most accurate) to quantify the benefits of projects, including SPI and is most commonly described as being the ratio of benefits to costs. However, a more accurate version of ROI uses Net Present Value (NPV) instead of the straight-line formula described above, while many practitioners also use the Internal Rate of Return (IRR) as a proxy for ROI (Brigham and Gapenski 1994; Higgins 1998; Ross et al. 1999; Tockey 2004). As we shall see in our discussion on ROI, there is very little clarity or consistency on which definition to use.

Based on the literature review conducted for the purposes of this research, the assertions of Solon and Statz (2002) and Zahran (1996) appear to have a considerable ring of truth to them. While at a high level benefits are categorized consistently in macro terms such as ROI, Quality, Defect Density, and Reduced Cycle Times, upon more detailed review results are not normalized nor are they consistent in how benefits are defined. To be fair to the researchers and practitioners who thankfully publish their work, such inconsistency is quite understandable, bearing in mind that these benefits are the actual results of SPI initiatives reported from different organizations, of different size, in different industries with different constraints and which are independently carried out.

Benefit	Yes/No	Comment
Increased revenue	No	Values vary broadly by market type and product type; revenue/employee is a normalized measure but not easily compared outside a given domain
Reduced cycle time	No	Interactions with processes and tools used, as well as specific type of product, make this difficult to compare
Reduced cost of operations	No/Yes	Basis of costs vary so widely by type of industry and culture, that comparison is very difficult. For comparable operations, such as corporate IT spending, there are usable benefits
Level of quality	Yes/No	If the quality level is established through a standard test of product performance, a recognized level of quality can be assigned. Otherwise, the methods used by different organizations and their different users are unlikely to be comparable
Increased productivity	Yes	Level of productivity (using function points to measure amount of work) works well
Cost	**Yes/No**	**Comment**
Costs of the program	Yes	Total cost (labor, training, speciality services, tools, travel etc.) are quite comparable, and they can be normalized by number of people in the organization benefiting from the SPI program

Table 2-6: SPI Benchmarks Critical Review (Solon and Statz, 2002)

In all, while there is a lot of published data to help demonstrate the benefit of SPI, there appears to be some legitimate concerns about how the studies are organized, reported on, and the data they contain. In addition, there are specific concerns about the effect of SPI on organizations.

2.9.2 Categorization of Benefits

Much of the literature deals with the results of SPI from individual organizations. As such, these reports are independent of each other and they report on the benefits which those organizations find beneficial and useful to measure. While there are certainly common benefits that are of interest to most organizations – ROI, Productivity, and Defect Density are amongst the most common – there are also benefits which, while of interest to the community as a whole, are mentioned in only a small minority of research reports. In order to not present a disjointed review of the various benefits, I have chosen to categorize the benefits under the most common categories as seen in the literature - ROI, Productivity, Quality, Cost, Reduced Cycle Time, and Soft benefits. A slight wrinkle in this approach is the fact that, in any one piece of literature, it is common to find the results for several categories. For example, Dion (1992; 1993) refers to several benefits – ROI, Productivity, Staff turnover (Soft Benefits), and Communications (Soft Benefits). The approach taken in this literature review is that the context of the research is described the first time that any of the benefits is discussed and, later, when discussing the other benefits under the various categories, just the article is referenced and not the context of the research.

2.9.3 Return on Investment - ROI

The National Software Quality Experiment (NQSE) is a mechanism for obtaining and storing samples of software quality data. It contains a micro-level database of quality data from various kinds of organizations, including industry, government, and military data. In this context, O'Neill (2003), provides a model for calculating the ROI on software inspections. In addition, using data in the NSQE database, he calculates the range of possible ROI values depending on the CMM level of an organization.

The CMM level of an organization is a determining factor because the higher the maturity level of an organization, the more emphasis is put on built in-quality. For example, if an organization employs modular programming methods, modular design etc. (some of the minimum characteristics of a Level 3 organization), there should be less flaws in the code and it should be more easily fixed if there are defects found – the quality is "baked in." Another factor that affects ROI is where the defect is found. The farther down the cycle in development that a defect is found, the more costly it will be to fix.

Briefly, O'Neill defines 3 Software Product Engineering KPAs being practiced:

- Ad-hoc Programming (AHP) – common in low maturity organizations
- Structured Software Engineering (SSE) – the minimum expectation for Level 3 organizations
- Disciplined Software Engineering (DSE) – this is the expectation for Level 4 and 5 organizations.

O'Neill defines ROI from Inspections as:

ROI = Net Savings / Detection Cost

Where:

Net Savings = Cost Avoidance – Cost to Repair Now

Detection Cost = Preparation Effort + Conduct Effort

Based on multiplier values from the NSQE database and using the above formulae, O'Neill has determined the ranges of ROI from Software Inspections (see Table 2-7).

SPE	Min ROI	Max ROI	Min Leakage Rate (KSLOC)	Max Leakage Rate (KSLOC)
AHP	18.06	21.92	8.75	12.5
SSE	4.43	5.81	2.50	3.75
DSE	0.76	1.14	0.3125	0.9375

Table 2-7: NSQE ROI on Software Inspection (O'Neill, 2003)

As we can see from the results in Table 2-7, there comes a point in high maturity organizations where ROI actually may actually decrease as a result of the high maturity of the organization. This should not be surprising as high maturity organizations have quality built in to their processes as opposed to applying ex post facto processes to ensure quality. In other words, a conscious decision must be made to enhance quality of the product at the expense of ROI.

Humphrey et al. (1991) described the Software Process Improvement initiative at Hughes Aircraft. Over a 4 year period from 1987 to 1990, the Hughes Aircraft company progressed to a CMM Level 3 organization based on two reviews carried out in 1987 and 1990 respectively. From a strict ROI point of view, the assessments cost Hughes Aircraft $45,000 and a further $400,000 over the two-year program of improvements. Hughes estimated the resultant savings to be about $2 million.

The effects of a CMM-based SPI program at Raytheon Inc. are described in (Dion 1992; 1993). Specifically, Dion discusses the program that was implemented at the Software Systems Laboratory (SSL), one of eight divisions within Raytheon, and which employs about 400 software engineers. When the article was published (in 1993) the program had been underway for approximately 5 years and had cost in the order of $1 million per year. The initiative itself had progressed the division from a Level 1 to a solid Level 3 and was in fact approaching a Level 4 assessment. Overall, his study found that ROI increased by a factor of 7.7 based on a sample of six projects.

Herbsleb et al. (1994b; 1994a) report on the Benefits of CMM-Based Software Process Improvement and provide some initial results of the implementation of CMM. The study consisted of publicly published reports as well as data that the SEI obtained from various early adopters of CMM. The data comes from a diverse group of organizations including Department of Defense (DOD) contractors, commercial organizations, and military organizations with a wide range of maturity levels. A summary of the aggregate benefits is detailed in Table 2-8.

Category	Range of Values	Median
Total yearly cost of SPI Activities	$49,000 - $1,202,000	$245,000
Years engaged in SPI	1 – 9	3.5
Cost of SPI per Software Engineer	$490 - $2004	$1375
Productivity gain per year	9% - 67%	35%
Early detection gain per year (defects discovered pre-test)	6% - 25%	22%
Yearly reduction in time to market	15% - 23%	19%
Yearly reduction in post-release defect reports	10% - 94%	39%
Business value of investment in SPI (ROI)	4.0 – 8.8	5.0

Table 2-8: Summary of Overall Results (Herbsleb et al, 1994b)

Boeing STS, a division of Boeing Inc. that supports space transportation programs for the Department of Defense and NASA, achieved a rating of CMM Level 5 in July 1996. Yamamura and Wigle (1997) describe some of the major benefits that are associated with Boeing's achievement. One of the first benefits that they find is that, because Boeing STS implemented CMM at the organizational level rather than at the program level, the various other benefits associated with CMM are more easily applied when either new personnel or new programs commence – the startup cost of new programs is much less than it might otherwise have been.

From a quantitative perspective, an analysis of cost-to-benefit ratios showed that there are definite savings associated with SPI. As an example, they describe the formal inspection process which increased design time by 25%, which was 4% of total development effort. This 4% increase resulted in a reduction in rework effort by 31%. This translated into a 7.7:1 ROI for formal inspection alone.

The Ogden Air Logistics Center's Software Engineering Division is a CMM Level 5 appraised organization. Over the years, however, they have kept many useful metrics, even though this is not officially required until CMM Level 4. Oldham et al. (1999) demonstrate the benefits associated with progression through the various levels of the Capability Maturity Model. They are at pains to point out, however, that while "it can be shown that tremendous improvements have been made in the TPS (Test Program Set) process capability in both the quality of software produced and the cost to produce that software, to correlate each change made over the years to specific quantitative improvements in process productivity or product quality is impossible. Instead, we can show general relationships and overall improvement across the years." In other words, they can show definite improvements, but they cannot tie those improvements back to specific initiatives. They calculated the ROI (computed based on cost per unit of deliverable product multiplied by the number of units delivered per year) as being

19:1. In addition, from a cost reduction perspective, the Automatic Test Equipment (ATE) product line now produces software updates at a savings of 70% compared to the original costs.

In reporting on the progression of the Oklahoma City Air Logistics Center (OC-ALC) from CMM Level 1 to CMM Level 4, Butler and Lipke (2000) reported that, for an investment of $6 million, the OC-ALC have calculated a reduction in cost of $50.5 million – an 8.4:1 ROI. In an independent study, undertaken this time by Software Productivity Research Inc., Butler (1995) determined that there was 7.5: 1 ROI, based on an investment of $1.5 million and savings of $11.3 million.

General Dynamics Decision Systems is a CMM Level 5 company that is involved in communications and information technology for both the military and the government. Out of approximately 1,500 engineers, approximately 360 are employed directly in software development. The division in somewhat unique in that it has kept extensive metrics all the way from Level 2 to Level 5. King and Diaz (2002) discuss some of the more important metrics that the General Dynamics Decision Systems has gleaned over the years, as well as explaining some of the more surprising results (see Table 2-9).

In order to calculate the below ROI data, General Dynamics made the following assumptions:

- SPI efforts were calculated at 2.5% of the base staffing of the 360 software engineers in the division
- 100 KSLOC size projects over two years
- 16 hours to fix a software defect after release
- Calculations do not take into account being able to apply existing resources in pursuit/execution of new business opportunities.

CMM Level Transition	**Cost for SPI in hours (2.5% of base)**	**Cost Savings on Re-work (hours)**	**ROI**
CMM Level 4 to 5	884	1,009	14%
CMM Level 3 to 4	1,310	2,744	109%
CMM Level 2 to 3	2,544	6,806	167%

Table 2-9: General Dynamics ROI results (King and Diaz, 2002)

As we may see from the figures above, an ROI of 1.14:1 is not a very dramatic ROI. However, King and Diaz make the point that the transition to Level 4 is very transitory and short lived, and most companies will progress from Level 3 to

Level 5 within a year so, in effect, we are dealing with a relatively small amount of time for the transition period.

To further support the argument that ROI increases as a result of implementation of CMMI, the SEI (2005) reported an increased ROI of between 2:1 and 27.7:1%, with a median increase in ROI of 4.7:1, based on 16 separate data points. Van Solingen (2004) presents two in-depth cases studies where he calculates the ROI from the implementation of SPI. The first case study is based on a systems development department in an industrial company that produces and services systems for fuel stations. The reported ROI is 1:1.13. The second case study is built on an organization that develops and services a software simulation package that can execute virtual tests using finite-element modelling and reported an ROI of 1:8.

In summary, there appears to be clear evidence of a correlation between increased ROI and implementation of various SPI initiatives. However, there also seems to be a trade-off between ROI and Quality, which would seem natural. In the case of SPI programs like CMM and CMMI, the higher an organization progresses up the maturity ladder, the more quality processes are put in place and therefore there is a tendency for ROI to taper off as a result.

2.9.4 Productivity

Boehm (1981), in his ground-breaking work on Cost and Effort estimation, describes the Constructive Cost Model (COCOMO), a method for determining cost and effort information for various project types, which is based on the traditional and now out-of-favour Waterfall life cycle model (Royce 1970). The COCOMO model itself consists of several models:

- A Basic model which is good for quick, early, rough order of magnitude estimates of software costs
- An Intermediate model, which is useful in the more detailed stages of project definition and design
- A Detailed Model, which is useful after a project has been fully specified.

All the qualitative data behind the model is based on a project database of 63 projects. Between the initial publication in 1981 and the publication of the COCOMO II model (Boehm et al. 2000), the database has grown significantly in size.

Many changes have occurred in the years since the original publication of COCOMO:

- As a civilization, we have become more dependent on software than we were in 1981
- New generations of software processes and products have totally changed the software landscape

As a result, Boehm et al. have updated the COCOMO model and come up with COCOMO II. To support various software marketplace sectors, COCOMO II provides a family of increasingly detailed cost estimation models.

From an SPI perspective, the most important update to the model is that it recognizes the effect of Process Maturity (PMAT) on the software development process. For COCOMO II, PMAT may be calculated in two ways:

- Based on the results of an organized CMM evaluation
- By determining the percentage compliance for each KPA

Clark (1997) proposes a mathematical model that segregates Process Maturity's influence on effort from other influencing factors. This work is incorporated into COCOMO II. According to Clark's research, he has demonstrated that a conservative estimate is that for a one level change or a 10% change in PMAT, there is between a 15.3% and 21% decreasing change in software development effort and, as a result, a consequent change in Productivity.

In a series of articles and technical reports Herbsleb and Goldenson (1995; 1996) and Herbsleb et al. (1997) discuss a survey they undertook in order to address assorted weaknesses of various previously published studies. For their sample, they used the SEI's appraisals database and limited themselves to appraisals conducted no less than one year before the study and no more than 3 years before it. In all, they found 155 appraisals that met this criterion. This population eventually led to the sending out of 167 questionnaires, with a subsequent return rate of 83%. In addition to maturity ratings, the respondents were asked to indicate where their organization stood on several performance measures, including ability to meet schedule and budget commitments, staff morale, product quality, customer satisfaction, and staff productivity. Their findings[2] are presented in Table 2-10.

[2] These results are taken directly from the graphs in the referenced paper and are therefore approximate to the actual results

	CMM Level 1 – Initial	CMM Level 2 – Repeatable	CMM Level 3 - Defined
Productivity	54%	68%	88%

Table 2-10: CMM productivity results (Herbsleb, Goldenson et al, 1995)

Brodman and Johnson (1995; 1996b; 1996a) investigate the effect of implementation of CMM Levels 1 through 5 on the ROI and productivity of organizations. A total of 33 companies were interviewed, 11 of which were surveyed via questionnaire, 13 by interview only, and the remainder by both. The companies selected were at various levels of the CMM. The first issue they had was in the definition of ROI. While there are some classical definitions of ROI (Brigham and Gapenski 1994; Higgins 1998; Ross et al. 1999), the government perspective of ROI was focused on the dollar value of ROI, while non-governmental organizations focused on benefits and effort involved. They concluded that the government is focused on dollar savings because of budgets that continue to get smaller, while commercial organizations think of various benefits which eventually add to the bottom line. Based on their study, they point to the following increases in productivity as a result of implementing CMM (see Table 2-11).

Category	Measurement	Data*
Productivity	Increase in productivity	10-20%, 90-100%, 50%, 15-20%, 130%, 12%, 6.4%, 35%
*Benefits are shown as a range of results within a single organization; results from different organizations separated by commas; all organizations not represented		

Table 2-11: Productivity Results (Brodman and Johnson, 1995)

A decision was made by Harris Information Systems Division to create a Data Processing Laboratory (DPL). The function of the DPL was to prototype software for independent research and development projects. As part of its development, the division started the adoption of CMM in 1990, achieving Level 3 in early 1994. Robeson et al. (1997) describe the DPL, its structure and the benefits it has derived from a combination of new technologies and SPI.

Every system developed by the DPL uses the same process, the only difference being the level of formality and documentation which depends upon whether the system is a prototype or whether it will ultimately be a full-blown production system. From beginning to end, the combination of software reuse, an architecture framework, an incremental development process, and a cadre of trained staff has produced a 2.5 times increase in productivity. Unfortunately, while these figures are encouraging, the paper does not explore how much of the benefits are attributable to SPI versus the other changes in the environment during the time period discussed.

Diaz and Sligo (1997) describe SPI in Motorola's Government Electronics Division (GED) and the various performance improvements brought about as a result of that division's implementation of CMM. The performance data was obtained from various projects whose CMM level was determined by the project's internal self-assessment. The results are detailed in Table 2-12.

SEI CMM Level	Number of Projects	Productivity (Relative)
1	3	n/a
2	9	1.0
3	5	0.8
4	8	2.3
5	9	2.8

Table 2-12: Productivity results (Diaz and Sligo, 1997)

Productivity is defined by them as the amount of work produced divided by the time to produce that work. They noted that there was a decrease in productivity between Levels 2 and 3 which they attributed to the sheer amount of new KPAs in Level 3. The total of all process improvement activities was approximately a 1.5% investment in base staffing (approximately $90,180) for a return of $611,200 or 677%. The returns were mainly realized through less rework due to less quality defects.

In 1999, the Oklahoma City Air Logistics Center (OC-ALC) was awarded the IEEE Award for Software Process Achievement in recognition of its efforts in the application of Software Process Improvement to its development and testing work. In their report, Butler and Lipke (2000) detail both the origins and results of this effort. The OC-ALC is responsible for developing and maintaining Test Program Sets (TSPs) that are used with Automatic Test Equipment (ATE). A TPS is the software, hardware, and documentation used to test avionics and jet engines. The organization itself is composed of about 360 software engineers that, for example, in 1999 performed services utilizing about 496,000 hours of labour having a value of $33.5 million. OC-ALC was one of the first adopters of the Capability Maturity Model, starting with their initial assessment as a Level 1 organization in 1989. In late 1992, they were re-assessed as a Level 2 and again in 1996 as a Level 4 organization. In 1998 they attained ISO 9001/TickIT certification. In order to justify their expenditures on SPI, OC-ALC has taken great efforts to keep metrics regarding the various benefits associated with SPI. Specifically, they have examined what they consider to be ROI from 3 different perspectives. From a productivity and defect perspective, OC-ALC has reported the following metrics (note that the productivity decrease in 1999 is attributed to the B-2 TPS project, where the Air Force levied a particularly detailed quality process). The results are detailed in Table 2-13.

	TPS Development Effort (man-hours)
1993	1600
1996	1200
1997	1150
1998	923
1999	1081

Table 2-13: OC-ALC Productivity Data (Butler and Lipke, 2000)

In addition to formal assessments, the Air Force requested an independent study of the benefits of SPI in 1994. This study was undertaken by Software Productivity Research Inc. and is described by Butler (1995). 4 projects were chosen as being representative of the work being undertaken by OC-ALC. The study was composed of both interviews and data collection. In the study, they determined that there was a 10 times increase in productivity from the baseline project to the most recent project as it stood in 1994 (while OC-ALC was at CMM Level 2, working its way to Level 4).

Further evidence to support increases in productivity as a result of SPI is provided by King and Diaz (2002) who provide a history of General Dynamics Decision Systems transition from a CMM Level 2 organization to a Level 3 one. Of the various benefits detailed in the article, probably the most interesting finding in this paper concerns productivity. King and Diaz assert that productivity is affected by factors other than just process maturity, the most important of which is technology change. In addition, as organizations increase in maturity, more re-usable high quality code becomes available, thus increasing the overall quality and productivity of code within the organization. Thus, maturity alone does not necessarily correlate to increased productivity as many papers on the benefits of SPI seem to imply. It is also interesting to note here that the authors also note that the transition from Level 3 to Level 4 does not result in a statistically significant change in productivity. This is attributed to Level 4 being more of a transitionary state for organizations on their way to Level 5 – organizations do not tend to stay very long at Level 4.

CMM Level	Productivity
2	1 x
3	2 x
4	1.9 x
5	2.9 x

Table 2-14: General Dynamics Productivity Benefits per CMM Level (King and Diaz, 2002)

Goldenson and Gibson (2003a) detail some preliminary results from the application of CMMI process improvement. In particular, they quoted a 30% increase in Productivity as a result of implementation of CMMI. In a follow-up to the initial 2003 report, the SEI (2005) attributed productivity increases as a result of implementation of CMMI of between 9 and 255%, with a median value of 62%. Garmus and Iwanicki (2007) report on the outcome of a project in which they were contracted to identify, select, and integrate measurement into a client's software development process to determine the impact of implementation of CMMI Level 3. They reported productivity increases of 132% (based on Function Point/Effort Month), and an effort reduction by 50%. Dion (1992; 1993) also reported Productivity increases of a factor of 2.3 in a 5 year time period as a result of implementing CMM. Also reporting productivity increases as a result of implementation of CMM is Herbsleb et al. (1994b; 1994a). Their report shows a productivity increase of between 9 and 67% over a wide range of maturity levels after implementing CMM, with the median increase being 35%.

With respect to CMM and CMMI there is consistent evidence of increases in productivity which coincide with the implementation of CMM/CMMI. However, there is also evidence to suggest that the rate of increase in productivity is not uniform or increasing as organizations implement higher CMM/CMMI levels. This is attributed to the work required to implement extra KPAs as organizations progress up the ladder. In addition, some research suggests that at least part of the productivity increases relates to technological innovation as a result of process improvement.

2.9.5 Quality

Perhaps one of the first reported improvements as a result of an SPI initiative was that of Fagan (1976; 1986). In his articles, Fagan reported that, as a result of the implementation of software inspections, for double the amount product source code, the defect density was the same as 2/3 of defect density for pre-implementation samples (IBM System/370); 0 defects were reported in return for a development resource reduction of 25% (AETNA); there were 0 defects in use for 9% reduction in development effort (IBM RESPOND); and 0.15 defects/KSLOC for 95% reduction in cost. Applying Fagan's Inspection Method to requirements specifications, Doolan (1992) reports that, for every hour invested in inspection, nearly 30 are re-couped.

Rubin (1993) undertook a study of more than 200 North American and 157 international organizations to determine the extent to which those companies applied rigorous software engineering techniques and to what extent software metrics were being used within the organizations. Of the international companies, 115 were from the United Kingdom. The UK-based companies appeared to be more mature (as measured by the SEI's CMM). From the analysis he carried out "it appears that introducing process rigor and maturity to the level of UK penetration with adequate toolset support has the potential to boost productivity by about 50% in the short term in contrast to current views on tools alone." Even though there was very little UK-based quality data in the study (as measured by defects per KLOS), it tended to be much better than the equivalent US data – 2 defects/KLOC for the UK vs. 4 defects/KLOC for the US.

The NASA Software Engineering Laboratory (SEL) was the first recipient of the IEEE Computer Society Software Process Improvement Achievement Award. In their report of SEL's achievements, McGarry et al (1994) described their approach, compared it to CMM and detailed the various benefits they derived from the implementation of the various SPI initiatives they undertook. The SEL was created in 1976 at the NASA/Goddard Space Flight Center (GSFC) for the purpose of understanding and improving the overall software process and products that were being created within the Flight Dynamics Division (FDD). The SEL is actually a partnership of 3 separate organizations:

- NASA/GSFC – responsible for project management activities
- University of Maryland - responsible for research activities
- Computer Sciences Foundation – responsible for development resources.

The SEL experiments are carried out on production FDD systems on projects ranging from 10 KSLOC to 1.5 million SLOC with a production staff of approximately 300 developers and analysts. SEL's approach to SPI is very different from the model used by the CMM. The SEL approach is a "bottom-up" approach where it assumes changes are driven by local goals, characteristics, requirements, and product attributes. CMM, on the other hand, uses a "top-down" approach where an organization compares itself to some generally accepted high-quality standard processes. From an impact perspective, SEL has found very positive benefits from its approach. It measures these benefits using defect density and cost/cycle time:

- *Defects*: from a range of 1.7 defects/KSLOC – 8.9 defects/KSLOC with an average of 4.5 defects/KSLOC, they have improved to 0.2 – 2.4 defects/KSLOC with an average of 1 defect/KSLOC.

From an SPI overhead perspective, SEL activities have cost approximately $25 million in an organization that has spent $250 million on software development and maintenance. This figure is reasonably in line with other quoted SPI overhead costs.

NASA's (National Aeronautics and Space Administration) SEL (Software Engineering Laboratory) has spent 10 years undertaking an SPI initiative at their Goddard Space Flight Center. Reporting on the SEL in 1994, Krasner et al. (1994) report significant improvement as a result of the SPI effort – predicted costs always within 10% of actual costs; only one deadline missed in 10 years; maintenance cost of code is approximately $20/hour, versus double that at other IBM software facilities; defects of 0.01 per KSLOC; and an increased error detection rate of 95%. In a follow-on report in 1995, Krasner (1995) reported a reduction in error rates of 75% between 1985 and 1993; a reduction of software development costs by 55%, increase of reuse by 300%; the average cost to develop a line of cost dropped by 10%; in addition, costs have become more predictable and there are now near-zero defects in the code produced there.

Advanced Information Services (AIS) is an independent software contracting organization that is based in Peoria, Illinois with a satellite office in the Chicago area and a subsidiary in Chennai, India. The AIS development group consists of between 20 and 35 engineers. The SPI initiative was started in 1992 and went through phases:

- Prior to 1992 – no SPI was being used
- 1992 – 1995, where the Capability Maturity Model was used.
- 1995 onwards, where both CMM and the Personal Software Process (PSP) were used together.

In 1992, AIS performed a self-assessment and determined that they were a Level 1 organization. In 1996, an independent assessor identified a few improvement opportunities and in 1999, AIS was assessed as a Level 3 organization. In 1999, AIS was awarded the IEEE Computer Society Software Process Achievement Award.

In their paper, Ferguson et al (1999) identified many benefits from the implementation of SPI. In particular, they identified:

- Decreased schedule deviation from 112% in pre-SPI, 41% in the CMM-only era, and 5% schedule deviation in the CMM + PSP era
- Effort predictability deviation went from 87% in the pre-SPI ere to 37% in the CMM-only era, and -4% in the CMM + PSP era
- System test duration dropped from 1.45 days per KSLOC in 1990 to approximately 0.4 days per KSLOC in 1998

- In comparing PSP to the two non-PSP eras, defect density dropped from 1 defect/KLOC for non-PSP to 0.35 after the implementation of PSP
- Productivity also increased after the implementation of PSP from approximately 7.2 LOC/hour to 8.6 LOC/hour.

Liu (2007) reports significant improvements as a result of Motorola's implementation of CMMI Level 5 in their sites in China. The metrics used in the study were Cost Of Quality (COQ), product quality, and estimation accuracy. Between 2003 and 2006, COQ was reduced from approximately 35% down to 25%, fewer defects were inserted into code and the faults per line of code was found to have been reduced by 13.01% from its pre-CMMI Level 5 level. In addition, initial effort estimation was found to have improved by almost 33%,

Herbsleb at al. (1994b) reported an early detection gain in defects discovered pre-test of between 6 and 25%, with a median gain of 22%. In addition, they reported a yearly reduction in post-release defects of between 10 and 94%, with a median reduction of 39%. Yamamura and Wigle (1997), in their report on their implementation of CMM Level 5, report on the defect detection rate. Initially, their processes were finding 89% of the defects – thus leaving 11% still baked in. After the SPI program, virtually 100% of all defects are found, reducing "escapees" to nearly 0. Putnam and Myers (1997) reported that Quality Improvements (by defect ratio) fell from just over 0.1 defects per 1 KSLOC to 0 defects per KSLOC. Several SEI technical reports, (Herbsleb and Goldenson 1995; 1996; Herbsleb et al. 1997) report increasing levels of Quality as organizations move up the CMM maturity levels (see Table 2-15).

	CMM Level 1 – Initial	**CMM Level 2 – Repeatable**	**CMM Level 3 - Defined**
Product Quality	76%	90%	100%

Table 2-15: Quality Results (Herbsleb et al., (1994b)

Brodman and Johnson (1995; 1996b; 1996a), based on the results of their surveys, report Quality increases as a result of implementation of CMMI (see Table 2-16).

Category	Measurement	Data*
Quality	Reduction in defects	10%, 80%, 50-70%, 50%
	Reduction in error rate	45%
Effort	Reduction in rework	5-10%
		from 40% down to 25% effort
		from 41% down to 11% of project cost
	Savings in test time	10 hours per 1 analysis hour
	Product error rate	from 2.0 down to 0.11 KSLOCS
		from 0.77K down to 0.13 per KNCSS
*Benefits are shown as a range of results within a single organization; results from different organizations separated by commas; All organizations not represented		

Table 2-16: Quality Results (Brodman and Johnson, 1995)

Robeson et al. (1997) in their paper report a 90% reduction in Defect Rates as part of their implementation on CMM Level 3. Diaz and Sligo (1997) report a significant increase in Quality as a result of Motorola's systematic implementation of CMM (note that Quality is defined by In-Process Defects / Millions of Earned Assembly-Equivalent Lines Of Code) (see Table 2-17).

SEI CMM Level	Number of Projects	Quality (In Process Defects/MAELOC)
1	3	n/a
2	9	890
3	5	411
4	8	205
5	9	126

Table 2-17: Quality Results (Diaz and Sligo, 1997)

Butler and Lipke (2000), as part of their research into the Oklahoma City Air Logistics Center's (OC-ALC) implementation of Level 4 CMM, found an increase in Quality as the center progressed from CMM Level 2 1992, to Level 4 in 1996 (see Table 2-18).

Year	Delivered Defects per KSLOC
1993	3.35
1996	0.35
1997	0.03

Table 2-18: Quality Results (Butler and Lipke, 2000)

An independent study undertaken by Butler (1995) confirmed the increase in Quality by ascribing a 90% reduction from the baseline project to the second project.

According to King and Diaz (2002), Quality (as measured in CRUD/KSLOC) increases as a result of the implementation of the new KPAs for each successive level in CMM – the Peer Review KPA is responsible for Level 3 values, the Quantitative Process Management and Software Quality Management KPAs in Level 4, and the Defect Prevention and Process Change Management KPAs in Level 5. They also note, as does O'Neill (2003), that for higher maturity levels, it becomes progressively more difficult to reduce defect density.

CMM Level	Percent Rework	CRUD Density per KSLOC
2	23.2%	3.20
3	14.3%	0.90
4	9.5%	0.22
5	6.8%	0.19

Table 2-19: Quality Results (King and Diaz, 2002)

As part of their research into the initial results of implementing CMMI, the SEI (2005), based on 20 separate data points, has attributed Quality increases of between 7 and 132%, with a median of 50% to the successful implementation of CMMI. From a defect perspective, McLoone and Rohde (2007) find a significant reduction in the Hours/KSLOC metric and another reduction in the Dollars/KSLOC cost while Garmus and Iwanicki (2007) report a reduction in defect density of 75%.

Given the studies analysed in this section, as organizations implement more quality-oriented processes, the quality of code improves. As more and more quality processes are included in the CMM/CMMI levels, the farther up organizations move in the CMM/CMMI maturity ladder, the higher the level of quality becomes. Unfortunately, as noted, this comes at a price as it becomes more difficult, and therefore more costly, to reduce the amount of defects the more mature an organization becomes. Not only is this evidenced by the data described in this section but, further evidence of this was noted earlier when discussing ROI in that, after a certain point, ROI can actually decrease as organizations become more mature.

2.9.6 Cost

Costs are obviously a critical component of the benefits of SPI from a financial perspective. Evidence of the financial benefit resulting from the implementation of SPI may be expressed as a ratio of cost to benefit (or vice versa) or as a discussion of costs and benefits separately. Unfortunately, however, much of the literature available tends to centre around ratios and not explicitly on straight costs and benefits.

Brodman and Johnson (1995; 1996b; 1996a) report cost savings as a result of implementing CMM (see Table 2-20).

Category	**Measurement**	**Data***
Cost	Project$ saved to $ invested	1.5/1, 2.0/1, 4/1, 6/1, 7.7/1, 10/1, 1.26/1, 5/1
	Project$ saved	$2-3.4 million
	Code problems during integration	20% of original value
	Decrease in cost of retesting	50%
	Cost savings of metrics program	50-300%, 40-290%
*Benefits are shown as a range of results within a single organization; results from different organizations separated by commas; all organizations not represented		

Table 2-20: Cost Savings (Brodman and Johnson, 1995)

In addition, Goldenson and Gibson (2003b) note some very important cost benefits arising from their early study on the adoption of CMMI. Among the more important benefits are a 60% reduction in work and fewer outstanding actions following pre-test and post-test audits and a 10% improvement in first pass yield leading to reduction in re-work. In a 2005 follow-up to this report, the SEI (2005) has published a new set of figures indicating a cost reduction of between 3 and 87% as a result of implementing CMMI, with a median cost reduction of 20%. This is based on 21 separate data points.

McLoone and Rohde (2007) identify 5 indicators of efficiency within Lockheed Martin Integrated Systems and Solutions (IS&S) and try to correlate these metrics with not only various levels of the SW-CMM but also between SW-CMM Level 5 and CMMI Level 5. Within US government organizations, payments to contracting organizations are frequently based on a Costs-Plus-Award-Fee basis. They report an increase in award payments between SW-CMM Levels 2 and 3 and a significant increase as they moved from SW-CMM Level 3 up to SW-Level 5 and another increase when they migrated from SW-CMM Level 5 over to CMMI Level 5. Significantly they report a decrease in Overhead Rates from SW-CMM Level 3 to CMMI Level 5. This is interesting in itself as there has been considerable discussion within the CMMI community as to the effect on costs of moving to CMMI Level 5.

A total elimination of late deliveries of software from August 2004 to January 2005 has been reported by Sapp et al. (2007). Their study compared two samples of completed projects which were randomly selected, stratified, and balanced to include similar projects and project managers. There were significantly less variances in cost after implementation of CMMI Level 5 – the 95th percentile confidence interval for the pre-CMMI Level 5 projects ranged from -6.4% to +7.78% while the post-CMMI Level 5 interval ranged from -1.0% to +7.4%.

McGarry et al. (1994), using the SEL's bottom-up SPI approach report that, using similar projects, the baseline cost ranged from 357 – 755 staff months with an average of 490 staff months before SPI implementation, to a new range of 98 – 277 staff months with an average of 210 staff months after SPI implementation – an over 50% reduction in cost.

In their technical reports, Goldenson, and Herbsleb (1995; 1996), and Herbsleb et al. (1997) report increasing abilities to meet budget as organizations move up the CMM maturity levels (see Table 2-21).

	CMM Level 1 – Initial	**CMM Level 2 – Repeatable**	**CMM Level 3 - Defined**
Ability to meet budget	41%	57%	67%

Table 2-21: Cost Benefits (Goldenson et al., 1995)

In summary, therefore, there is considerable evidence to support assertions that SPI does indeed reduce cost. We must be mindful, however, that cost is only one factor that organizations typically wish to drive down and, it could be argued, that many organizations would put quality ahead of cost as a driving benefit of SPI.

2.9.7 Reduced Cycle Time

In their study on Schlumberger's Software Improvement Program, Wohlwend & Rosenbaum (1994) describe the CMM-based Software Process Improvement program at Schlumberger's Laboratory for Computer Science. Schlumberger's main businesses include well-site exploration, and production services for the petroleum industry; testing and electronic transaction products; and metering products which are sold to public utilities, governments, laboratories and industrial plants worldwide. As many of their products contain software, Schlumberger founded a central Computer Science laboratory in 1989. It is under the auspices of this laboratory that Schlumberger's software improvement program was managed. For their purposes, Schlumberger concentrated on progressing to CMM Level 2. Table 2-22 shows the results of the metrics they captured. In general, it appeared that it took 12 – 18 months for significant improvement to occur.

KPA	Pre-Level 2 Metrics	Level 2 Metrics
Requirements Management	• 34 validation cycles (code/test/re-code)	• 15 validation cycles • Productivity doubled
Software Project Planning	• 51% on schedule in 1990	• 89% on schedule in 1991 • 94% on schedule in 1992
Software Project Tracking and Oversight	50% schedule adherence rate in 1990	87% schedule adherence rate in 1991 99% schedule adherence rate in 1992
Defect Density	400K NCSS; average defect rate of 0.22 KNCSS	700K NCSS, average defect rate of 0.13 KNCSS
Software Quality Assurance	1989 – 25% of total product defects were post-release defects discovered by the customer	• 1990 – 18% reported by customers • 1991 – 10% reported by customers

Table 2-22: SPI results (Wohlwend and Rosenbaum, 1994)

Putnam and Myers (1997) found that the schedule and cycles times for the average Automatic Test Equipment development time has dropped from approximately 1120 working days in 1991 to about 200 in 1996 while Schedule Variance is now less than 5%, compared with an average variance of 70% for DOD projects.

In their study, Lawlis et al. (1995). were able to show that for CMM Levels 1, 2, and 3, there is a correlation between CMM rating and the Cost Performance Index (CPI) and Schedule Performance Index (SPI) for organizations where:

$$CPI = \frac{BCWP}{ACWP}$$

$$SPI = \frac{BCWP}{BCWS}$$

and

BCWP = Budgeted Cost of Work Performed

ACWP = Actual Cost of Work Performed

BCWS = Budgeted Cost of Work Scheduled

The data for the study was gathered from Air Force software development projects that met the following criteria:

- Projects tracked software-specific cost and schedule data in Cost/Schedule Control Systems Criteria format
- Contractors were rated using the SEI's CMM
- Relevance of cost and schedule data to the rating could be established.

Eleven DOD contractors and 31 software projects fell into these criteria. Using this data, Lawlis at al. were able to show a correlation between CMM rating and the cost and schedule performance of a generally representative sample of historical development contracts. In their technical reports, Goldenson, et al. (1995; 1996) and Herbsleb et al. (1997) report increasing abilities to meet schedule as organizations move up the CMM maturity levels (see Table 2-23).

	CMM Level 1 – Initial	CMM Level 2 – Repeatable	CMM Level 3 - Defined
Ability to meet schedule	41%	57%	80%

Table 2-23: Schedule Results (Goldenson et al., 1995)

Diaz and Sligo (1997) report a significant decrease in Cycle Time as a result of Motorola's systematic implementation of CMM (note that Cycle Time is defined as the amount of calendar time for the baseline project to develop a product divided by the cycle time for the new project) (see Table 2-24).

SEI CMM Level	Number of Projects	Cycle Time(X Factor)
1	3	1.0
2	9	3.2
3	5	2.7
4	8	5.0
5	9	7.8

Table 2-24: Cycle Time results (Diaz and Sligo, 1997)

Butler and Lipke (2000), as part of their research into the Oklahoma City Air Logistics Center's (OC-ALC) implementation of Level 4 CMM, have found a decrease in Cycle-time as the centre progressed from CMM Level 2 1992, to Level 4 in 1996 (see Table 2-25).

	TPS Development Cycle-time (months)
1993	13
1996	12
1997	12
1998	12
1999	18

Table 2-25: Cycle Time results (Butler and Lipke, 2000)

Goldenson and Gibson (2003b) note some very important schedule benefits arising from their early study on the adoption of CMMI. Among the more important benefits are an increase in the percentage of milestones met from approximately 50% to approximately 95%, a decrease in the average number of days late from approximately 50 to fewer than 10, an increase in the though-put resulting in more releases per year, an improved and stabilized Schedule Performance Index, a reduction by half the amount of time required to turn around releases, a 15% improvement in internal on-time delivery, an improved predictability of delivery schedule, and a decrease in schedule variances decreased as process maturity increased. In a follow-up report published in 2005, the SEI (2005) has again indicated a reduced schedule time of between 2 and 90%, with a median reduction in schedule of 37%, based on 19 separate data points.

Sapp et al. (2007) report a total elimination of late deliveries of software from August 2004 to January 2005. From a schedule variance perspective, the 95th percentile confidence interval for the pre-CMMI Level 5 projects ranged from -52.0% to +2.0% while the post-CMMI Level 5 interval ranged from -2.5% to +0.2%. Garmus and Iwanicki (2007) similarly report a reduction in project duration of 50%.

There have been a wide variety of time-related benefits reported as a result of SPI implementation. These time-related benefits are reported as either a reduction in time-related project delays or adherence to published project schedules.

2.9.8 Soft Benefits

The literature reports many soft benefits resulting from the implementation of SPI. These reports are summarized in Table 2-26 and are reported by source. Where specific quantitative data has been provided in the literature, this is included in the "Qualitative Results" column.

Source	**Soft Benefit**	**Qualitative Results (where published)**
Humphreys and Snyder (1991)	Increased pride in developers' work	
	Increased quality of work life	
	Less overtime hours	
	Less serious issues to deal with	
(Dion 1992; 1993)	Less turnover in software engineers due to less late nights and weekends spent in work	
	Improved communications	
Yamamura and Wigle (1997)	Increased customer satisfaction	97% – 100% customer satisfaction in surveys
	Increased employee satisfaction	Employee satisfaction survey increased from a mean of 5.7 to a mean of 8.3 where a value of 1 is highly dissatisfied and 10 is extremely satisfied

Table 2-26: Summary of reported soft benefits of SPI

Putnam and Myers (1997)	More constrained in performing job	10 agreed, 4 saw no difference, and 4 said they were less constrained
	Easier to perform duties	13 thought it was much easier, 2 felt it was a little easier, 2 about the same, and 1 said it was harder
	Fewer surprises	13 agreed, 4 saw no difference, and 1 felt there were more
	More input into project plans	12 felt they had more input, 2 felt they had a little more, 2 felt they had the same, and 2 felt they had less
	CMM efforts had been successful	Unanimous
	Better quality software produced	16 felt they now produced better quality and two felt the quality had not changed
Hyde and Wilson (2004)	Improvement in quality of work life	
	Increased organizational communication	
	Increased organizational learning and efficiencies	
	Increased level of coherency in organizational culture	
	Neutral in relation to the improved ability of the organization to attract new staff, retain staff, and develop the careers of professionals	
Goldenson, Herbsleb, and Zubrow (1995; 1996; Herbsleb et al. 1997)	Increased customer satisfaction	78% at Level 1, 69% at Level 2, and 100% at Level 3
	Increased staff morale	22% at Level 1, 50% at Level 2, and 60% at Level 3

Table 2-27: Summary of reported soft benefits of SPI (cont.)

2.10 Critical Analysis of SPI

To say that SPI in itself is the silver bullet for the software development process would be less than disingenuous. Nothing in life is free and SPI is no exception to this rule. Various criticisms such as cost, rigidity in approach, and the size of the administrative overhead associated with SPI have all been levelled at SPI strategies – or more particularly *Formal* SPI (the definition of which shall be given shortly). Indeed the core work of this thesis, where it is now possible to identify which specific Process Areas should be performed as a response to a business objective, is a response to the rigidity and cost criticisms levelled at SPI. According to Jones (2008):

> "[…] the value of the CMM and the CMMI are directly proportional to the size of the software applications being developed. For small applications of 1,000 function points or lower, the CMM and the CMMI tend to reduce productivity but raise quality. This is due to the overhead built into the CMMI approach. […] In fact, for applications larger than 10,000 function points, CMM Level 5 has about the best record of success yet recorded."

Fayad and Laitinen (1997) have reservations about the necessity of the assessment of an organization's CMM level of maturity as they contend that it may sometimes be wasteful for various reasons including cost and repeatability. Gray and Smith (1998) also report on what they believe to be several limitations on software process assessment. Chief amongst those concerns are the repeatability and reproducibility of software process assessments as well as how one arrives at the definition of an ideal model. Gray and Smith are also of the opinion that "a substantial number of [SPI benefits] have not been demonstrated." The issue of repeatability and reproducibility of software process assessments is also reflected in the work of Bollinger and McGowan (1991). In the general sense of demonstrating positive results, Galin and Avrahami (2006) find that no one paper provided conclusive evidence of the benefit of CMM program investment." Herbsleb at al. (1997) also point out that there are only a few data points available regarding the actual cost of the implementation of SPI programs.

Pressman (1996) criticizes CMM in particular. His chief concern is that it "represents a destination, not a road map" where management frequently does not provide adequate resources for proper implementation and, even when resources are committed, it is frequently conducted by committee, with predictably poor results. Commitment of resources and staff to SPI is also cited by Abrahamsson (2001) as a reason for failure of SPI programs. El Emam and Briand (1997) report that many organizations find that the early adoption of certain process areas is more effective than in the recommended sequence. Ashrafi (2003) investigated the impact of SPI methodologies on software quality, specifically CMM and ISO 9000-3. His empirical study indicates that in general process improvement enhances software quality factors but the level of impact is dependent upon the methodology used. Specifically for CMM however, the results were "somewhat inconsistent." Blanco et al. (2001) in their review of 91 returned questionnaires from 273 organizations who implemented various process improvement experiments found that the organizations in question saw very little evidence of quantitative benefits and, regarding the subjective evaluation of the business benefits achieved, most respondents agreed that the only benefit was an increase in the product's quality. Shaikh et al. (2009), in their study on the strengths and weaknesses of Maturity Driven Process Improvement as implemented by CMM/CMMI, find that many of these efforts fail because of lack of management commitment, wrong motivation for the personnel working on the effort, and that is it not suitable for small organizations.

There have been legitimate criticisms levelled at some SPI models, particularly for smaller-sized projects. In the case of these SPI models, irrespective on the size of the projects, it is up to individual organizations to balance the increased costs of assessment and accreditation, the increased size and overhead associated with the SPI model, and any issues arising from rigidity in application of the model with the benefits to the organization as a whole.

2.11 Business Process Improvement Literature Review

The section explores both Business Process Improvement (BPI) and the impact and integration of IT and IT processes and techniques with BPI. In the same way that Software Process Improvement endeavours to optimize the software process, BPI endeavours to optimize the underlying business processes within organizations. According to Povey (1998), "BPI is a broad term that covers a continuum from incremental continuous improvement (CI) at one end to the radical re-engineering of the businesses and its processes, characterized as business process re-engineering (BPR), at the other." MacDonald (1997) reflects this when he categorizes BPI into three different approaches – process improvement, process redesign, and process re-engineering. Valiris and Glykas (1999) also agree that there is a continuum in BPR ranging from incremental to radical. The methodologies in use today have their origin in the earlier discipline of "organization and methods" from the 1970s (Webster 1973). Over time, BPI matured and again gained prominence through a series of books and research papers in the 1990s. Within the gamut of BPI and BPR, there is a specific class of business processes which can be described as being of high task complexity and high knowledge complexity and are referred to as "knowledge-intensive" processes (Remus and Schub 2003) and which Dalmaris et al (2007) refer to as Knowledge-based Business Process Improvement (KBPI). Clearly the intersection of both BPI and SPI falls within this category of business processes. Central to much of the work on BPI is the role of IT in BPI. As early as 1990, Davenport and Short's work (1990), for example, contended that "IT can also have a stronger role in business process redesign than that of a useful tool". They think of the relationship between IT and Business as being recursive and that thinking about information technology should be in terms of how it supports new or re-designed business processes, rather than business functions of other organizational entities. The existence of this extremely close relationship is also supported by Valiris and Glykas (1999). Hammer (1990) and Hammer and Champy (1990) also echo these sentiments when they states that we should "use the power of modern information technology to radically redesign our business processes in order to achieve dramatic improvements in performance."

According to Beer et al. (1990), attaining business objectives is the ultimate target for any change program. Dyba (2005), in a quantitative survey of 120 software organizations, demonstrated that SPI success is positively associated with business orientation. Unfortunately from an SPI perspective, however, Debou and Kuntzmann-Combelles (2000) contend that the major bottleneck to the success of SPI initiatives is the lack of business orientation in how the program is run. They attribute this bottleneck to several factors including inadequate allocation of resources, the belief that SPI is just a level certification exercise, and the lack of software management skills. However, they believe the number one cause of SPI program failure is the "general lack of business orientation of the program and the actors, reflected by the missing link with business strategy and goals." They back up these assertions with experiences and lessons learnt from two industry sources in the telecommunications and defence industry. In a similar theme, Reiblein and Symons (1997) point out that a shortcoming of the ISO-9001 and CMM approaches to SPI "is the lack of explicit connection to the business goals of the organization in question." Specifically with regard to CMMI, Liu et al. (2006) state that there exists a disconnect between business goals and maturity levels.

As a result of the apparent disconnect between BPI and SPI, some researchers have tried to bridge the gap. Damij et al. (2008) propose an object oriented methodology called TAD (Tabular Application Development) in the field of business process modelling and improvement. The first three phases deal with business process identification, modelling, and improvement. In the paper, they apply their methodology to a business process representing a surgery, though there is nothing to stop the process being studied being SPI. Hinley and Reiblein (1995) present a case study on assessing improvements to software processes in relation to meeting organizational need and management objectives. The case study is based on the application of GQM (Basili and Weiss 1984) as a means to determine how closely a process is to achieving business goals and objectives. The case study used reduction in the cost of software maintenance as a business goal and then used GQM to measure compliance with that objective. Reiblein and Symons (1997) assert that one of the shortcomings of the ISO-9001 and CMM approaches to process improvement "is the lack of explicit connection to the business goals of the organization in question." The representation that these models have of the business is the ideal world, not the world that an organization actually resides in. They contend that the business sees this as a deficiency as the initiation of a meaningful process improvement plan can only take place if the current state of affairs and not the idealized world is used. As a result, they propose comparing the *assessed* capability profile of an organization against the *target* capability profile of an organization and they describe a method which uses business goals and objectives to arrive at the target capability profile. Thus they can use an ISO/IEC 15504 assessment to couple business goals and objectives to SPI. A different approach to the integration of business objectives and SPI is taken by Liu et al. (2006). In their paper on the integration of business goals and CMM, as well as a follow-on paper on CMMI (Sun and Liu 2010), they describe a methodology using Quality Function Deployment (QFD) (Akao 1990) and Analytical Hierarchical Process (AHP) (Saaty 1980) to help organizations achieve the integration of business processes with CMM and CMMI. The results of the studies were validated by a domain expert from Toshiba. Hayashi and Kataoka (2008) used QFD to integrate a defined business process, subcontract management, with ISO/IEC15504 for an unspecified automaker's system development related company and were able to "confirm concrete effectiveness to decrease rework."

2.12 Conclusion

Software Process Improvement has been around in various guises from the outset of software development; only in recent times has the area become a discipline in its own right. As the first projects which were undertaken were reasonably small and focused on manageable application domains, improvement was organic in nature and did not require a separate initiative or discipline to manage this improvement. However, as project size and complexity increased, it became more important to manage improvement and increase discipline within projects. Out of this, SPI was born.

As SPI was now a clearly identifiable domain, one of the first questions asked was regarding the benefit of implementing SPI. As a separate discipline or process around software development, it was now possible to identify the costs associated with SPI and, as a result, to be able to potentially quantify (where possible) the Return On Investment (ROI) of SPI. As we have seen in this chapter, there is a large body of evidence surrounding the benefits associated with the implementation of SPI.

However, there are several challenges associated with the interpretation and use of this evidence. In the first case, there is a lack of uniformity in the definition and interpretation of the metrics/indicators used as evidence of the benefits of SPI. Different researchers and practitioners use the same metric to mean different things. Secondly, for various reasons, not all companies, even when using standard industry definitions for metrics, use the same metrics in their studies. The effect of this is that, while there may be quite a lot of research, it is sometimes difficult to find like-metrics upon which to base comparisons. Thirdly, companies may be reluctant to divulge information for commercial reasons, particularly if the results of their SPI paints them in a worse light than the rest of their peers in the industry.

In addition to SPI, both BPI and BPR have been around for quite some time and it has long been recognized that IT has a very close relationship with these fields, beyond the mere use of IT and related systems as a tool to achieve BPI/BPR. It has also been recognized from an SPI perspective that full integration with an organization's business goals and objectives is an essential ingredient for successful implementation of SPI. Several methodologies have been proposed to integrate business objectives and SPI, such as using GQM or QFD as the basis for the methodology. The proposed methodologies, however, appear to be closely coupled to various SPI methodologies such as CMM, CMMI, and ISO/IEC15504. Some methodologies appear to be quite promising but, unfortunately, don't appear to have yet been extensively validated. In addition, no general, all-purpose methodology or model which can be readily used by practitioners has been identified during this review. This thesis presents research to further address this gap through the development and validation of the Rosetta Stone Methodology and the Rosetta Stone Implementation for CMMI.

3 Research Methodology

3.1 Introduction

The purpose of this chapter is to provide a solid theoretical foundation for the research methods and techniques used in this thesis as well as providing the reasons behind the particular research methods chosen and used in this work.

In order to provide a structure around this, I used a research model described by Jenkins (1985) and which, according to him, is based upon "an amalgam of work by authors such as Stone (1978), Kaplan (1964), Clover and Balsley (1984) and Buckley (1976). The paradigm concepts are derived from (Kuhn 1996)." While even Jenkins himself admits that the research process' sequential arrangement is an over-simplification, it is, as several other researchers point out, essential to have a clear, well-laid out research process (Parnas and Clements 1986; Creswell 2007; Cooper and Schindler 2008). Interspersed with the theoretical discussion on the nature of research and methodologies, the discourse will place particular emphasis on the methods and methodologies which are of particular relevance to this thesis as well as why and how they were employed.

3.2 Jenkins' Research Process Model

In his article, Jenkins (1985) presents a very high-level, step-by-step overview of the process of conducting research in the field of Management Information Systems (MIS). Two fundamental assertions are made – (i) that there is a fundamental research process that is applicable to all research and (ii) that there are a large number of research methodologies applicable to MIS research. He argues against a 'one best way' approach to conducting MIS research. The assertion of no "one best way" approach to conducting MIS research has been echoed by several other researchers in the field (Antill 1985; Fitzgerald 1997; Avison 1998).

Jenkins details eight steps in the process. In summary, the steps are:

1. **Idea** – getting the initial idea for the research process
2. **Library Research** – perform a literature review of the area of the proposed research
3. **Research Topic** – define a clear, unambiguous statement of the research objective

4. **Research Strategy** – select the appropriate research method(s) to be used in the research process
5. **Experimental Design** – using the appropriate research strategy(ies), design the actual experiment to affirm/reject the research topic
6. **Data Capture** – conduct the research as defined in the experimental design phase
7. **Data Analysis** – review the results of Data Capture
8. **Publish Results.**

3.3 Idea and Library Research

The first step in the model is to come up with an idea worthy of research. This is typically unstructured and may be influenced by any number of factors including having a real-world need to solve a particular problem or, alternatively, having to focus on an area in order to pursue a higher-level degree. I have been working in the IT organizations of Financial Services organizations for the last 20 years. During that period, I have spent my time in the development, project management, and Project Management Offices (PMO) areas of several large Wall Street firms including Salomon Brothers, Goldman Sachs, and Lehman Brothers. During my time there, all these organizations had been aware of various SPI methodologies but, for various reasons, the IT organizations within these firms chose never to implement any of them. The methodologies were looked upon as being not very business-focused and people were not sure of the ROI resulting from their implementation. In addition, they were looked upon as lacking the ability to be implemented in an a-la-carte fashion from which one could drive a business-focused objective to a particular SPI process area. Another reason for the lack of uptake on SPI is a more general one – the apparent difficulty in building links between research and professional practice and, in fact, this last reason may be the primary driver for the lack of uptake. Moody (2000) provides a compelling discussion on this topic and, as can be seen in Figure 3-1, I saw the need to connect SPI research and a financial services IT organization.

> The idea phase of the research, therefore, was that: *the researcher was interested in applying SPI to his work in the financial services industry. Thus the initial idea was on how to determine if SPI provides value and, if so, how it could be useful in his day-to-day work where the IT domain is much more business-oriented than IT-oriented.*

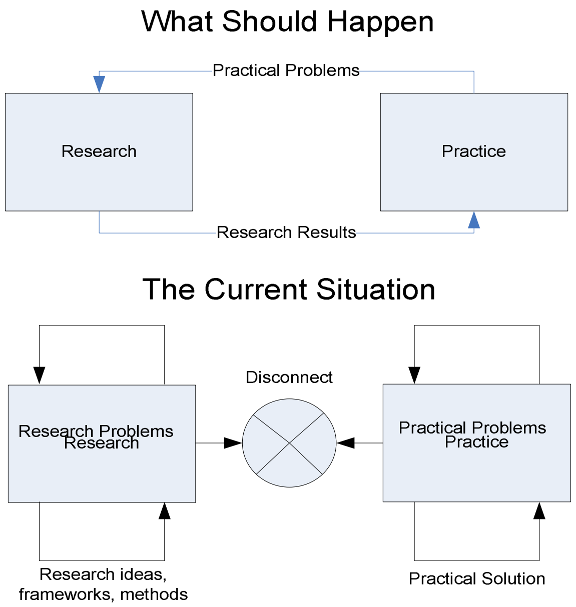

Figure 3-1: Disconnect between Research and Practice (Moody, 2000)

The next step is to perform what Jenkins terms a "Library Research" (Jenkins 1985). This is now more commonly called a Literature Review and was presented in Chapter 2. The Literature Review for this thesis focused on the more common SPI methodologies currently in use, the benefits of SPI, and the financial methods used to quantify various benefits as a result of the implementation of SPI, and on the interaction between BPI and SPI.

The Literature Review was initiated by performing a keyword search of various online research portals, particularly the IEEE and ACM portals. The keywords used for the search were:

- Software Process Improvement/SPI
- Software Process Improvement/SPI Benefits
- ROI Software Process Improvement/SPI
- CMM/CMMI Benefits
- ROI CMM/CMMI.

The list of sources in which the review was principally carried out was:

- IEEE Digital Library
- ACM Digital Library
- Wiley InterScience (Computer Science).

This search yielded a large amount of results which were then reviewed for usefulness and relevance. Each result contained further references which were then obtained and reviewed and which then yielded further references and so on. This practice has been continuous during the research period

There was quite an amount of evidence in the literature on the benefits of SPI but, as seen in Chapter 2, the various measurements/metrics were not consistently defined, the articles focused on metrics which were important only to a particular organization, and were IT-focused and not homogenous.

3.4 Research Objective

Following the Literature Review, the research objective became clearer:

> *To develop and evaluate a methodology that allows organizations to achieve specific organization-pertinent benefits using existing SPI methodologies and techniques.*

The drivers for this new method are organization-focused but at the same time the work relies heavily on aspects of both software engineering and information technology. Sommerville (2007) defines software engineering as "an engineering discipline that is concerned with all aspects of software production from the early stages of system specification to maintaining the system after it has gone into use" while Information Technology (IT), according to the OGC (2007), is defined as "the use of technology for the storage, communication, or processing of information. The technology typically includes computers, telecommunications, applications, and other software. The information may include business data, voice, images, video etc. Information Technology is often used to support business processes through IT services." Clearly, software engineering is concerned with software while IT is concerned with all aspects of technology which impact a business. This work uses aspects of software engineering such as SPI in conjunction with IT concepts such as ROI and as such sits between both disciplines. For example, what SPI process areas should be implemented to achieve increased productivity or reduce time to market? Objectives like these are critical to an organization and have not typically been the focus of SPI research.

3.5 Research Strategy

3.5.1 Research Philosophies

Research philosophies are the subject of intense debate within the field of IS and are frequently presented as dichotomies though, as we have already discussed, they do not need to be mutually exclusive. Several of the more frequently mentioned (Fitzgerald and Howcroft 1998; Cornford and Smithson 2005) are:

- *idiographic vs. nomothetic vs. constructive*
- *positivist vs. interpretivist*
- *quantitative vs. qualitative.*

As Fitzgerald (1997) and Fitzgerald and Howcroft (1998) point out "it should be noted that these dichotomies are not all at the same level of abstraction as some of them are more overarching than others and some are almost synonymous."

Many of the areas within IT - such as Information Systems (IS), Integrated Systems Development (ISD), and Management Information Systems (MIS) - are applied sciences. According to Moody (2000), there are two primary objectives of an applied discipline – to increase knowledge (theoretical) and to improve practice (practical). They focus on practical applications of science rather than being purely theoretical in nature. Like other applied disciplines such as medicine, IS relies on other disciplines such as computer science and organizational behaviour for their theoretical basis. According to Galliers and Land (1987):

> "Traditionally, the topic [of research] has often been viewed as residing, for the most part at least, within the province of technology. Increasingly, however, both IS academics and practitioners have begun to realize it is more appropriate to extend the focus of study to include behavioural and organizational considerations"

The reason that this is important is that we must realize that there are potentially many different research strategies and approaches that can be used to perform research within IT. As mentioned earlier, this position is supported by several researchers in the field (Antill 1985; Fitzgerald 1997; Avison 1998; Fitzgerald and Howcroft 1998).

3.5.2 Research Style – Idiographic, Nomothetic, or Constructive?

Based on an analysis of the fundamental assumptions of seven major schools of thought in IS development, Iivari (1991) has suggested that there are 3 distinct styles of IS research – constructive, nomothetic, and Iiiographic. *Constructive* research deals with "models and frameworks which do not describe any existing reality but rather help to create a new one, and which do not have any physical realization"; *Nomothetic* research is "concerned with exploring empirical data in order to test hypothesises of general character about phenomena studied"; and *Idiographic* research "is concerned with exploring particular cases or events providing the richest picture of what transpires."

> *Given the research objective in this thesis of developing and evaluating a methodology that allows organizations to achieve specific organization-pertinent benefits using existing SPI methodologies and techniques, this research uses a constructive research style.*

3.5.3 Positivist vs. Interpretivist

Positivism

According to MacKenzie (1977), in his 1972 work on Positivist Science, Kolakowski (1972) characterizes positivism in terms of 4 rules: phenomonalism, nominalism, the fact-value distinction, and the unity of scientific method. Phenomonalism deals with the elimination of all abstractions from science; Nominalism states that words, abstractions, and generalizations do not give any new insight into the world and should thus be excluded; fact-value distinction states that facts should be separated from values; and unity of scientific method states that the scientific method is valid for all forms of inquiry. Hirshcheim (1985) alters this slightly by stating that positivism is based on 5 pillars:

1. Unity of the scientific method
2. Search for Humean[3] causal relationships
3. Belief in empiricism
4. Science (and its process) is value-free
5. The foundation of science is based on logic and mathematics.

Unity of scientific method has the same meaning as used by Kolakowski. The Ssarch for Humean causal relationships is based on the desire to find causal relationships of items under study. Belief in empiricism is based on the belief that everything has to be measurable and discrete. Science is value-free is based on the

[3] Named after David Hume (1711 - 1776), a prominent philosopher and economist

desire for science to be impartial – facts are facts and do not have politics or emotions associated with them.

Of particular relevance to this research work is Orlikowski and Baroudi's (1991) observation that IS research can be classified as positivist if there is evidence of formal propositions, quantifiable measures of variables, hypothesis testing, and the drawing of inferences about a phenomenon from a representative sample of a stated population.

Interpretivism

At its highest level, intepretivism is the view that all knowledge is a matter of interpretation. From an intepretivist's perspective, not every scientific inquiry can be divorced from a context, viewed within a pure vacuum, or be discretely measured. Fitzgerald (1997) states that "intepretivism is concerned with understanding and interpreting human behaviour from the actor's own frame of reference. There is no universal truth or reality to be found."

In a more detailed description of interpretivism, Lee (1991) states:

> "The interpretive approach [to organizational research] maintains that the methods of natural science are inadequate to the study of social reality. This school of thought takes the position that people, and the physical and social artefacts that they create, are fundamentally different from the physical reality examined by natural science. Unlike atoms, molecules, and electrons, people create and attach their own meanings to the world around them and to the behaviour they manifest. "

Of particular relevance to this research is the statement by Klein and Myers (1999) that "IS research can be classified as interpretive if it is assumed that our knowledge of reality is gained only through social constructions such as a language, consciousness, shared meanings, documents, tools, and other artefacts." Due to the fact that the work undertaken for this thesis is unique in nature and there is a lack of established quantitative research in the area, much of the interaction is by necessity at a social level primarily using shared meetings.

In summary there appears to be no "one best way" approach to research and, as can be seen from the fundamental characteristics of both approaches, certain areas naturally lend themselves to either the positivist or interpretivist research approaches.

As the Research Objective involves defining a new methodology to support a business-oriented SPI implementation paradigm, and there was no apparent evidence available in the literature that could be used as a basis for a study, an interpretivist approach was deemed the most appropriate.

3.5.4 Quantitative vs. Qualitative

Quantitative techniques are firmly based around mathematics and statistics while qualitative techniques tend to be much less mathematically-focused. Quantitative techniques have their roots in the positivist school of research. As a result, many of the discussions on positivism vs. interpretivism also fall over into qualitative vs. quantitative debate. However, it must not be assumed that these two techniques are mutually exclusive to each camp – as Silverman (1998) recognizes "In IS, as in other social sciences, the critique of quantitative [and qualitative research] can lead to an oversimplified opposition between positivism and negativism." This point of view is further supported by Kaplan and Duchon (1988) who advise that qualitative and quantitative approaches can be integrated, providing a richer picture of the area under study. In their work, Glesne and Peshkin (1991) outline the predisposition of qualitative and quantitative modes of enquiry (see Table 3-1). Silverman (2006) neatly summarizes the naturally inherent characteristics of both approaches (see Table 3-2).

The researcher must understand when it appropriate to use either method. Quantitative approaches are most useful, for example, when the area under research can be reduced to numerical and statistical values, when there is a strong desire to generalize the results, or when relationships can be mathematically modelled. A qualitative approach, for example, is more appropriate when the results are narrative/linguistic in format, when the context of the study is important, or when an understanding of a phenomena is to be explored.

As this subject area has not been extensively explored and the population of subjects who have the expertise to have a knowledgeable discussion on a model such as the one developed is quite small, a qualitative approach was chosen.

	Quantitative Mode	Qualitative mode
Assumptions	Social facts have an objective reality	Reality is socially constructed
	Primacy of method	Primacy of subject matter
	Variables can be identified and relationships measured	Variables are complex, interwoven, and difficult to measure
	Etic (outside's point of view)	Emic (insider's point of view)
Purpose	Generalizability	Contextualization
	Prediction	Interpretation
	Causal explanations	Understanding actors' perspectives
Approach	Begins with hypotheses and theories	Ends with hypotheses and grounded theory
	Manipulation and control	Emergence and portrayal
	Uses formal instruments	Researcher as instrument
	Experimentation	Naturalistic
	Deductive	Inductive
	Component analysis	Searches for patterns
	Seeks consensus, the norm	Seeks pluralism, complexity
	Reduces data to numerical indices	Makes minor use of numerical indices
	Abstract language in write-up	Descriptive write-up
Researcher Role	Detachment and impartiality	Personal involvement and partiality
	Objective portrayal	Empathic understanding

Table 3-1: Qualitative vs. Quantitative technique comparisons (Glesne & Peskin, 1991):

Quantitative	Qualitative
Hard	Soft
Fixed	Flexible
Objective	Subjective
Value-free	Political
Survey	Case Study
Hypothesis testing	Speculative
Abstract	Grounded

Table 3-2: Quantitative vs. Qualitative comparisons (Silverman, 2006)

3.6 Research Approach

Research methods[4] are those techniques which are used by researchers to perform the actual study which is the subject of the research. Vogel & Wetherbe (1984) have identified a taxonomy, which, according to Cornford and Smithson (2005) has been used many times as the basis of writings about information systems research. Jenkins (1985) further added to this list to arrive at the following set of research methods:

- Mathematical modelling
- Experiment Simulation
- Lab Experiment
- Free Simulation
- Field Experiment
- Adaptive Experiment
- Field Study
- Group Feedback Analysis
- Opinion Research
- Participative Research (also known as Action Research)
- Case Study
- Archival Search
- Philosophical Research.

Having already arrived at the Research Paradigms and Approach (constructionist, interpretivist, and qualitative) to be used in the study, the number of possible research approaches from Jenkins' list is considerably narrowed down. Choudrie and Dwivedi (2005), have modified an initial classification of the research approaches of Galliers (1992) and Mingers (2003) to classify them as either positivist or interpretivist (see Table 3-3).

[4] Also known as research methods or research approaches. For the purpose of this thesis and to be consistent with Jenkins, we shall use the term "research approach."

Research Philosophy	Mingers (2003) Classifications of Research Methods	Galliers' (1992) Classification of Research Methods
Positivist	Observation (passive), measurements, and (statistical analysis)	Laboratory Experiment
	Experiments	Field Experiment
	Survey, questionnaire, or instrument	Survey
	Case Study	Case Study
		Theorem Proof
		Forecasting
	Simulation	Simulation
Interpretivist	Interviews	Subjective/Argumentative
	Qualitative content analysis	Reviews
	Ethnography	Action research
	Grounded theory	Descriptive/interpretive
	Participant observation	Futures research
		Role/game playing
Methods involving interventions	Action Research	
	Critical theory	
	Consultancy	

Table 3-3: Classification of Mingers' (2003) and Galliers' (1992) Research Methods (Choudrie and Dwivedi, 2005)

Cornford and Smithson (2005) note that, since information systems include people, there is the variability and psychological opaqueness of the human mind and human intention to contend with. For interpretive researchers, social science, not natural science, is the immediate reference discipline. The following interpretivist approaches were ruled out (the naming convention below is based on (Mingers 2003)):

- *Qualitative Content Analysis* – this concerns the analysis of texts and artefacts for the occurrence of specific keywords, categories, or terms. As the proposed model is a new model, no data currently exists to review and therefore this approach cannot be used.
- *Ethnography* – this is a technique with its origins in anthropology. Essentially a researcher immerses himself/herself in a culture. In terms of IS research, this means that the researcher would become a passive member of a team whose job would be to implement the research in question. Given the potential cost of undertaking a real-world project on which to test the model, it was not possible to find candidates willing to test out the research
- *Grounded Theory* – uses a range of empirical sources to generate theories and plausibly explain relationships. This research was not concerned with such results and therefore grounded theory was ruled out.

- *Participant Observation* – this is the case where the researcher is an active participant in the process. This was ruled out because the field work would have been impractical for the researcher
- *Role/Game Playing* (from Galliers' taxonomy) – the model being proposed is a generic model which can be adapted to various benefit hierarchies and SPI models. As a result, there is no one-specific set of rules which can be applied for a role/game playing approach.

For this particular work, the research consisted of 2 parts:

- Creating the Rosetta Stone Methodology and the RS-ICMMI instance mapping
- Validating both the methodology and the RS-ICMMI mapping. The validation process was carried out using expert opinion.

Using the interpretivist approach, the RS-ICMMI mapping was built using the CMMI 1.1 standards (SEI 2002a; 2002b) in conjunction with a modified version of Basili's GQM framework (see section 3.7.1) along with feedback from 3 SPI practitioners using a general interview approach. The methodology was then extrapolated from the instance model.

3.7 Experimental Design

3.7.1 GQM

In order to create the model, a variation of Basili's Goal-Question-Metric (GQM) approach was used (Basili and Weiss 1984; Basili 1992; Basili et al. 1994). The basis of GQM is that, for an organization to measure itself in a meaningful way, it must use a top-down approach where it first defines its goals, then define the questions which characterize the way the achievement of a goal is going to be performed and, finally, define a set of data which is associated with the questions being answered. This takes a 3-levelled approach:

1. Goal: A goal is defined by an organization.
2. Question: A question, or set of questions, are defined and are "used to characterize the way the assessment/achievement of a specific goal is going to be performed based on some characterizing model" (Basili et al. 1994).
3. Metric: A set of data associated with the questions to be able to answer the question in a quantifiable way.

This is shown graphically in Figure 3-2.

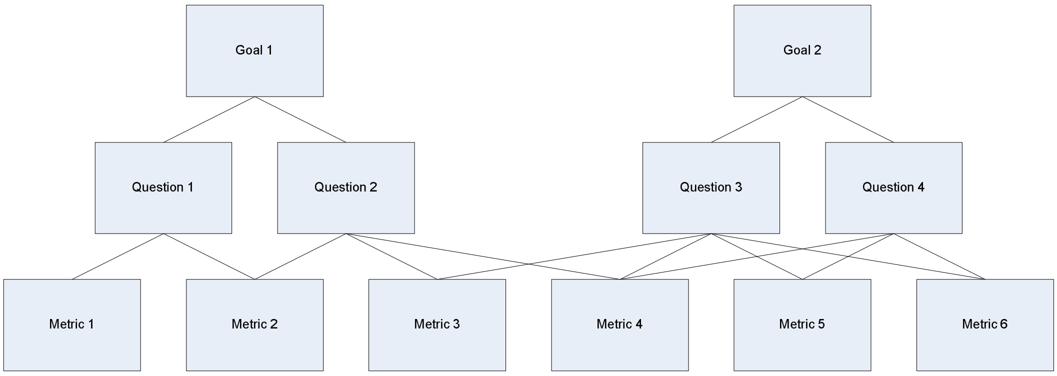

Figure 3-2: GQM Approach (Basili, 1992)

The model used in this work has been modified slightly from Basili's model in that the Question becomes "what Process Area or Areas solve the business objective defined in the Goal level." As a result, the 3 levels now become:

1. Goal: What Business Objective does the Business wish to solve?
2. Question: What Process Areas are directly or indirectly relevant to the Goals?
3. Metric: What metrics can be defined and captured to quantify improvement or regression from the objective?

This is represented graphically in Figure 3-3.

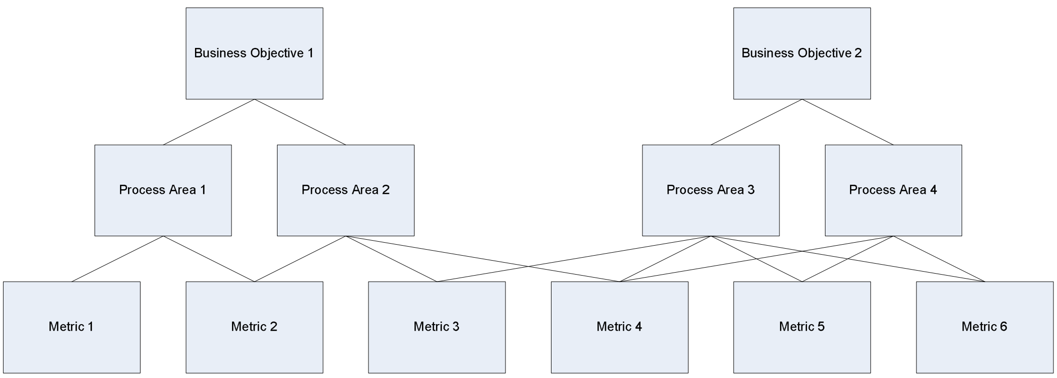

Figure 3-3: Modified GQM Approach

Following this approach, the Rosetta Stone Methodology and the RS-ICMMI mapping instance as described in Chapter 4 was developed.

3.8 Validation of the Rosetta Stone Methodology

To review the methodology and the mapping instance, two separate validation exercises were carried out. The first validation exercise, a general review of the usefulness and applicability of the proposed methodology, was performed using an interpretivist approach. The method deemed most suitable for the validation phase of the methodology was the Interview approach. In particular, an expert panel approach was used which focused on gathering the views of SPI experts. The second validation phase, the review of the RS-ICMMI mapping instance, was also interpretivist in nature as it revolved around asking expert opinion on the proposed cause-and-effect relationships between Process Areas and Benefits was gathered and analysed.

3.8.1 Expert Panel

An expert panel may be defined as being a group of experts in a particular area who can subjectively assess the impact of a proposed action or idea. It is a widely practiced technique for making predictions (Shepperd and Cartwright 2001) and has been successfully applied in previous IS research work. As Hakim (1987) notes, small samples can be used to develop and test explanations, particularly in the early stages of work. Examples of successful previous studies which have used small samples to gain expert feedback include Dyba (2000), El Emam and Madhavi (1996b) and Beecham (2003). The value of such expert knowledge has also been acknowledged in Rosqvist et al. (2003) where expert judgement was used for the evaluation of software quality. In addition, several studies, including those of Kitchenham et al. (2002), Beecham et al. (2005), and Leuesen and Vinter (2001) have used expert panels to reliably predict information which was subsequently demonstrated in practice.

For this study, the researcher invited 25 experts to participate, 19 interviews were set up while 17 experts finally gave their opinion. For further review, the questionnaire that was given to the experts is detailed in Chapter 5 and a high-level biography of all the participants is provided in Appendix C.

3.8.2 Data Capture

To capture the data, a series on one-on-one interviews were held with the experts. Where possible, those were held in person; otherwise they were held over the phone. All interviews were captured using a digital recorder with the express consent of the interviewees.

3.8.3 Data Analysis

In order to formally analyse the comments from the various interviews, a content analysis technique was used. The particular content analysis technique used in this work is described in Miles and Huberman (1994), Patton (2001), and Slowey and Richardson (2006) and consists of reviewing all interviews, identifying categories, and coding them. After the text from all the interviews is coded, all the coded texts are reviewed together, giving a holistic view of all similar comments across the entire set of interviews. This results in the identification of a set of codes (see Table 3-4).

To summarize, the validation phase of the Rosetta Stone Methodology was performed using an expert panel interview approach where all the responses were captured and analysed using content analysis.

Area	Code	Description
Benefits	BEN_ALL	Beneficial to all companies?
Benefits	BEN_LAR	Beneficial to large companies?
Benefits	BEN_MED	Beneficial to medium companies?
Benefits	BEN_SMA	Beneficial to small companies?
Benefits	BEN_SME	Beneficial to SMEs?
General	GEN_FIN_COM	Final Comments
Interviewee	INT_EXP_O	Interviewee's other experience
Interviewee	INT_EXP_S	Interviewee's SPI experience
Research Methodology	RM_MAP	Any other ways to arrive at the mapping or any comments on approach
Rosetta Stone	RS_COM	Comments about the generic model
Rosetta Stone	RS_OTHERS	Is the interviewee aware of any other methodologies like Rosetta Stone?
Rosetta Stone	RS_VALID	Do you consider this to be a valid generic approach?
Rosetta Stone Instance	RSI_COM	Comments
Rosetta Stone Instance	RSI_GEN_BEN	Benefits of this approach
Rosetta Stone Instance	RSI_REVIEW	Comments about what is good (or bad) about the model
Rosetta Stone Instance	RSI_HIER	Comments about the hierarchy of the IBM model
Rosetta Stone Instance	RSI_IBM	Comments about the IBM benefits model
Rosetta Stone Instance	RSI_MAP	Comments about the mapping
Rosetta Stone Instance	RSI_PRIOR	Comments about the prioritization process
Rosetta Stone Instance	RSI_FW	Recommendations for future work on Rosetta Stone
Rosetta Stone Instance	RSI_USE	Would you use the model
SPI	SPI_BEN	Any non-standard benefits of SPI
SPI	SPI_BEN_BUS	Are there any other business-driven approaches out there?
SPI	SPI_COM	Comments
SPI	SPI_DRIVERS	Why would an organization undertake SPI

Table 3-4: Content Analysis Codes for Rosetta Stone Interviews

3.9 RS-ICMMI Benefits Mapping Validation Process

Once the Rosetta Stone Methodology was created and the validation process completed, a mapping between a benefits model and an SPI methodology was completed to create a mapping instance. That mapping consists of primary, a secondary, or no relationship between a particular Process Area and a particular IGSI-ISM Benefit. Each of these individual mappings, or the lack of a mapping, must be reviewed by experts to validate the mapping. At a high level, the basic premise of the validation interviews therefore is that, for each Process Area/IGSI-ISM Benefit combination, an interviewee is asked if they agree that the IGSI-ISM benefit resulted from the implementation of the Process Area (PA) in question. In addition to a binary answer (yes/no), interviewees were further asked for any specific evidence or opinion they had on a particular mapping. In all, 294 separate questions on benefit/process area impact were asked of 10 interviewees.

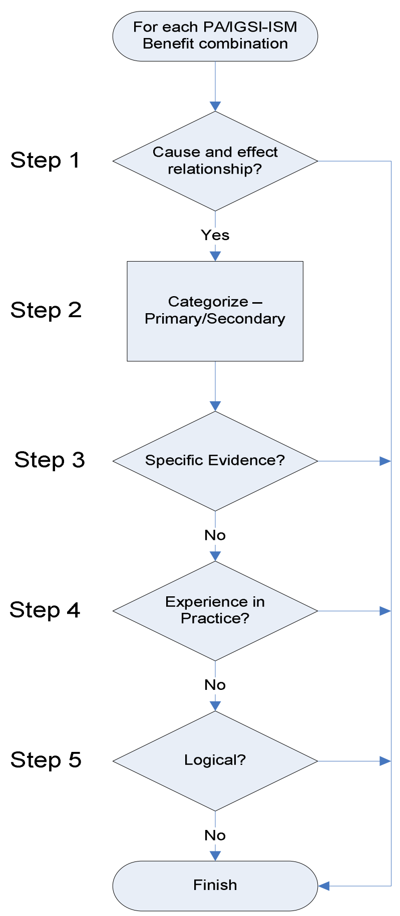

Figure 3-4: Question Flow for validation of PA to IGSI-ISM Benefit map

3.9.1 Primary Vs. Secondary

The Rosetta Stone Methodology recognizes the importance of primary versus secondary benefits (see section 4.4.3) and uses this categorization to drive recommendations on the priority of implementation of Process Areas (see section 4.4.4). Primary versus secondary therefore is an important element in the benefit mapping and was specifically asked as part of the validation process. In addition, there is also the possibility that a particular Process Area/Benefit combination may not have any cause and effect relationship. Therefore the cause and effect relationships may have 3 separate possibilities – a primary relationship, a secondary relationship, or no relationship.

3.9.2 Degrees of Evidence

As part of the validation process, interviewees were asked to provide evidence or reasons such as experience in practice to support a cause and effect relationship between a Process Area and a Benefit. As a result, the questions were organized in order of the importance of the evidence provided by interviewees. This question flow is illustrated in Figure 3-4. To begin with, the interviewee is asked to confirm if there is a relationship at all (Step 1). If there is a relationship, it must then be categorized as being either a primary or a secondary relationship (Step 2). The interviewee is then asked (Step 3) if he has any specific evidence to support his opinion that there is a relationship between a Process Area and a Benefit. If so, it is documented. In the absence of a specific example that the interviewee can describe, the interviewee is asked if he has seen a relationship in his general experience (Step 4). If so, it is documented. If not (Step 5), then the interviewee is asked if he believes that logically there should be a relationship between a Process Area and a Benefit.

3.9.3 Interview Sampling Method

Based on the initial mapping (see Appendix E), a total of 97 separate requests for supporting evidence would be required for evidence to determine if the mapping is correctly identified for primary expected benefits. If we require at least two interviewees to answer each mapping question, 2 * 97 questions would be required – a total of 196 separate interview questions. To ask the same question for Secondary Benefits would require 269 such questions, or 538 questions if we wish to have the same question answered at least twice. To verify the benefits which are neither primary nor secondary benefits would require 159 questions, or 318 questions if the same question if required twice. The total number of questions which need to asked of interviews is therefore 194 + 538 + 318 questions = 1,050 questions. As this is a very large number of questions, for practical purposes a method was devised to reduce the scope.

I therefore focused on the level 2 mapping for initial validation of benefits and interviewed 10 experts (see summary of experience in Appendix D). Based on the RS-ICMMI mapping, there are 31 benefits ascribed to the Level 2 Process Areas and there are 116 non-primary benefits. In order to ensure all Process Area/Benefit mappings are covered twice, a total of 62 primary mapping questions must be answered and a total of 232 non-primary questions must be answered. With 10 interviewees, 6 interviewees must answer 6 primary benefit questions and 2 interviewees must answer 7 primary benefit questions. To answer the non-primary questions, 8 interviewees must answer 23 non-primary questions and 2 interviewees must answer 24 questions. Table 3-5 summarizes the exact number of questions per interviewee and the percentage of questions asked. Questions were assigned to interviewees in random order and in such a way that no one interviewee was asked to answer the same relationship twice.

Interviewee	**Number of Primary Questions**	**Number of Secondary Questions**	**% of Questions**
Interviewee 1	7	24	9.48
Interviewee 2	7	24	9.48
Interviewee 3	6	22	10.50
Interviewee 4	6	23	10.14
Interviewee 5	6	24	9.80
Interviewee 6	6	23	10.14
Interviewee 7	6	23	10.14
Interviewee 8	6	22	10.50
Interviewee 9	6	23	10.14
Interviewee 10	6	24	9.80
Total	**62**	**232**	**100**

Table 3-5: Summary of Questions per Interviewee

Randomness is achieved by assigning actual interviewees to the placeholders that were previously defined as Interviewees 1 – 10 using a random number table.

3.9.4 Compliance to Expectations

To determine how the initial mapping compares to the experts' opinions, I created a metric called "Compliance to Expectations." This metric compares the results of the interviews to the expectations of the instance model and can have the following values:

1. 100% compliance – both interviewees for each Process Area/Benefit combination agree with the model
2. 50% compliance – only one of the interviewees for each Process Area/Benefit combination agrees with the model
3. 0% - none of the interviewees agrees with the model.

This metric was used when updating the RS-ICMMI model to reflect interviewees' comments. For mappings which were either 100% compliant or 50% with expectations, no change was made to the RS-ICMMI mapping. For those mappings which were 0% compliant with expectations, the mapping was altered to reflect the opinions of the interviewees.

3.10 Summary

In this chapter, I have provided a theoretical background on research methodologies, those which are particularly relevant to IS, and those which are used in particular in this work. Using Jenkins' research model, I have shown how research has progressed from the initial idea stage through to the decision to use the expert panel method to elicit feedback on the model proposed. In following chapters I shall detail the actual questionnaire used, how the results of the study were collated, what those results were and provide a summary biography of each of the experts whose opinion was gleaned in this course of this work.

In summary, the research approach and techniques used are constructionist, interpretivist, and qualitative. For the validation phase of the Rosetta Stone Methodology, the expert panel technique is used and for the validation phase of the specific RS-ICMMI instance mappings, expert interviews were carried out to establish evidence of benefits.

4 The Rosetta Stone Objective-Driven SPI Methodology – translating between Organizational Objectives and SPI

4.1 Introduction

Until recently, IT organizations have tended to drive the SPI agenda in order to achieve IT benefits as a primary objective, and organizational benefits as a secondary objective. However, this is typically not the way the commercial world works – in the commercial world it is the business which drives IT, not the other way around. To achieve a business-oriented focus, the Rosetta Stone objective-driven SPI Methodology (RSM) has been developed and will be presented in this chapter.

To aid in more easily understanding the methodology, this chapter is logically presented in 3 parts:

1. Description of the meta-model model. The meta-model provides an abstract representation of the relationships between business objectives, process areas, and the indicators/metrics which may be used to demonstrate progress or regression of the implementation of SPI within an organization (section 4.2).
2. Description of the methodology used to arrive at a concrete implementation of the meta-model (section 4.3).
3. Example of the operationalization of the methodology to create an instance of a mapping. The implementation presented here is a mapping from the IGSI-ISM benefits model, a generic benefits model developed by IBM India (Goyal et al. 2001), to the CMMI (Staged) SPI model and will hereafter be referred to as the Rosetta Stone IGSI-ISM to CMMI implementation, or RS-ICMMI for short (section 4.4).

4.2 The Rosetta Stone Meta-Model

4.2.1 Background

Many valuable studies of the benefits resulting from implementation of CMM/CMMI and Software Process Improvement (SPI) in general have been undertaken over the last several years. These studies discuss SPI using at least one of 3 separate axes:

- **Organizational Focus** – were the studies carried out solely within one organization or were they carried out as general studies across an industry or several industries? Examples of cross-organizational studies include (Herbsleb et al. 1994b; Brodman and Johnson 1995; Herbsleb and Goldenson 1995; Brodman and Johnson 1996b; Herbsleb and Goldenson 1996; Clark 1997; 1999; Ferguson et al. 1999; Clark 2000) while organization-specific examples include (Humphrey et al. 1991; Dion 1992; 1993; Basili and Green 1994; McGarry et al. 1994; Wohlwend and Rosenbaum 1994; Buchman 1996; Diaz and Sligo 1997; Butler and Lipke 2000; Harter and Slaughter 2003)
- **Improvement Methodology** – was the SPI program undertaken using CMM/CMMI, ISO/IEC 15504 or some localized Software Process Improvement program? Several different methodologies and programs have been or are currently the subject of several studies. General methodologies include CMM/CMMI (SEI 2002b; 2002a), ISO 9000/9001 (International Standards Organization 1994; 2000), and ISO/IEC TR 15504 (ISO 2003; 2004a; 2004b; 2004c; 2006), while examples for specific process improvement activities include the use of Software Inspections (Fagan 1986; O'Neill 2003), Software Re-use (Lim 1994) and the impact of tools (Bruckhaus et al. 1996)
- **Metric Focus** – was the study undertaken to focus on explicit metrics that the concerned parties were specifically interested in improving/monitoring or were the metrics in question used to highlight the results of SPI? For example, Grady (Grady and Caswell 1987; Grady 1992; 1997) focuses on setting up company-wide metrics programs, while Capers Jones focuses on particular metrics that measure programmer productivity (Jones 1986; 1991).

This is illustrated graphically in Figure 4-1.

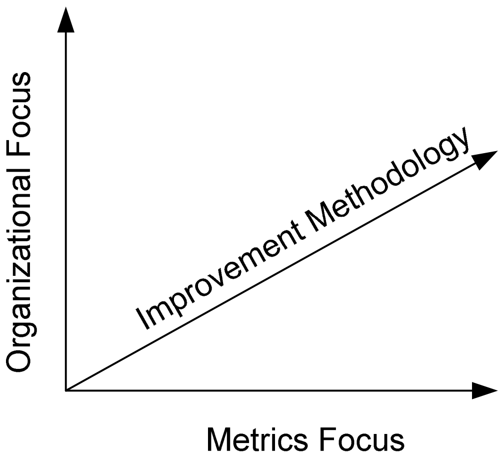

Figure 4-1: Axes of SPI studies

Many of the papers on ROI/SPI benefits focus on at least two of the 3 axes mentioned in the previous paragraph. The Rosetta Stone Meta-model is a consolidated model which allows practitioners to view organizational focus, metrics, and SPI programs concurrently using one, unified framework – a "Rosetta Stone" of SPI, if you will, that allows translation between SPIs, Benefits, and Metrics.

4.2.2 Rosetta Stone Meta-Model Overview

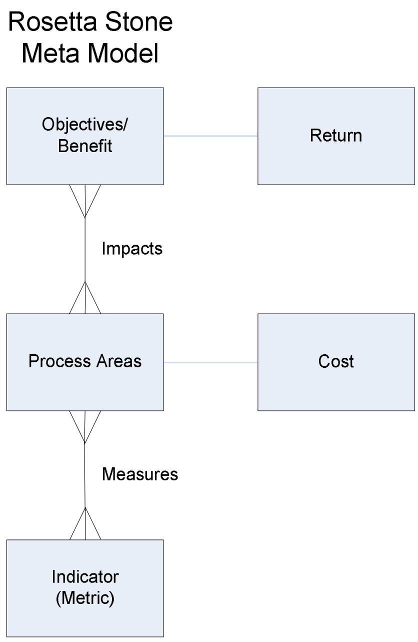

Figure 4-2: Rosetta Stone Meta-Model

The Rosetta Stone meta-model is composed of 5 basic elements, as well as the relationships between them, and is graphically illustrated in Figure 4-2.

4.2.3 Elements

The most important element is the *set of Business Objectives* or *Benefits* which an organization wishes to achieve. If possible, these should be hierarchical so that the achievement of one should lead to the achievement of others. For example, if the on-time delivery of projects is achieved (one possible business objective) then this should result in better customer satisfaction (another possible business objective). Each benefit should have some form of *Return* associated with it – some way of determining, frequently quantifiable but sometimes qualitative, the value of the benefit to an organization. Returns are meaningful to the Business and, as such, are typically not IT-type metrics such as defects/KSLOC or defects/function point – unless, of course, the Business is primarily an IT-focused business. For example, if productivity were the objective, it might be possible to say that, for an x% increase in productivity, there should be an increase in profits of y%. For each Objective, there is at least one *Indicator* - a set of metric(s) that are an indication that a particular benefit has occurred. In other words, a set of indicators that can prove (or disprove) that progress is being made towards a specific benefit – a way to measure a benefit. Process Areas (PAs), using the standard SEI nomenclature, are the actual SPI processes being implemented by IT. Each PA has a *Cost* associated with it – the sum of all financial costs that are incurred in order to implement a PA.

In order to implement the methodology, the practitioner must first choose which Objectives are most relevant to the Business and then choose which SPI model is most appropriate for their organization. These two entities then drive the choice of Costs, Returns, and Indicators. This will be discussed in detail in section 4.3.

4.2.4 Relationships

Perhaps the most complicated part of this model is in defining the relationships between the Objectives/Benefits model and the PAs. At this point, it is sufficient to say that, for the generic model, it is understood that there are relationships and these relationships identify how to drive from Business Objectives to PAs. To illustrate the relationships through an example, if we were to consider a Process Area such as Requirements Management, many professionals would intuitively suggest if requirements are managed in accordance with the CMMI definition of that Process Area, there should be less cycles wasted due to an incorrect understanding of current requirements (a Benefit) and that, as a result, during testing there should be less rejected defects raised (an Indicator) as requirements will be in accordance with code. The Cost of this may be more money spent on requirements management tools while the Return would be a project delivered on time. How this is done in a non-abstract way is dealt with in detail in section 4.3.

4.2.5 Return, Costs and ROI

In the majority of organizations, where profit is a primary goal, benefits should ultimately lead to a monetary impact on the organization. In other words, there should be some form of Return On Investment (ROI). One of the main advantages of this methodology is that it is now possible to tie SPI to specific benefits due to the fact that the benefits may be defined at a very granular level. It must be recognized, however, that in some cases it is difficult to measure the monetary value of a benefit – for example, how can a dollar value be put on increased team morale?

We recognize, however, that there are other types of organization who do not have profit as their primary objective and, as a result, may not have the same emphasis on the monetary impact of benefits. If we take universities as an example, while expenses are certainly high on their agenda, their organizational mission tends to be based on the education of their students and the advancement of learning. More appropriate measures in a university environment may be the number of students being taught or the ranking of the university in relation to other universities.

There are several ROI calculation methodologies widely used throughout industry today. Whichever one is chosen will depend upon individual project and organizational circumstances such as how rigorous the calculation has to be, how familiar project managers are with financial models, and the availability of appropriate discount rates. As Phillips (1997) notes, the term ROI "is often misused." Frequently it is a generic term for specific calculations. Given this, how is it possible to evaluate the monetary benefits that come about as a result of an organization's investment in SPI?

There are several popular methods for evaluating projects (Brigham and Gapenski 1994; Higgins 1998; Ross et al. 1999):

1. Net Present Value (NPV)
2. Internal Rate of Return (IRR)
3. Return on Investment (ROI)
4. Profitability Index (PI).

All of the above ROI methods compare the monetary returns resulting from the implementation of SPI to the associated cost of funding it. In the case of the Rosetta Stone Methodology, the return on the Software Process Improvement is compared to the implementation cost of the Process Areas in question. Great care must be taken, therefore, to not only capture the monetary equivalents that accrue from the benefits of SPI but also the cost of implementing them.

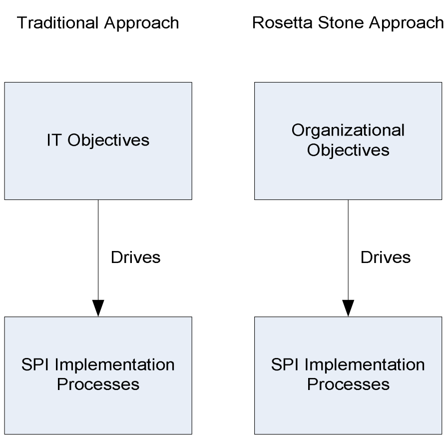

Figure 4-3: Traditional vs. Rosetta Stone SPI Approach

The main benefits of using this model are that users are able to:

- Achieve specific business objectives by targeting particular Process Areas to implement in order to achieve those objectives
- See what benefits may be derived from implementation of which particular Process Areas
- Given a set of existing metrics and values, determine what Process Areas may be more readily and quickly implemented than others.

4.3 The Rosetta Stone Methodology

Having described the meta-model, we now turn our attention to the Rosetta Stone Methodology – the translation process whereby an abstract meta-model is transformed into a concrete implementation which may be readily used by practitioners. At a high level, each abstract entity as described in Figure 4-2 must be replaced with a concrete entity. Figure 4-4 illustrates both the individual steps of the methodology as well as the levels at which various actions are taken.

One important factor in the whole mapping process is the ability of the practitioner to influence the mapping from abstract to concrete. Depending on the individual organization and the practitioner's position within the organizational hierarchy, we must recognize that a practitioner will sometimes have more or less influence to decide on the mapping. In many organizations, particularly large organizations, a practitioner's ability to influence will increase as he or she progresses farther down the steps as defined in Figure 4-4. This is because frequently the choice of both the SPI methodology (step 1) and benefits model (step 2) is performed at a strategic level within an organization; the mapping between benefits and process areas (step 3), the determination of the implementation order (step 4) and the determination of which metrics to use (step 5) are performed by SPI practitioners; and the monitoring of costs and benefits (step 6) is performed by the "front-line" staff involved in the running of projects and support organizations.

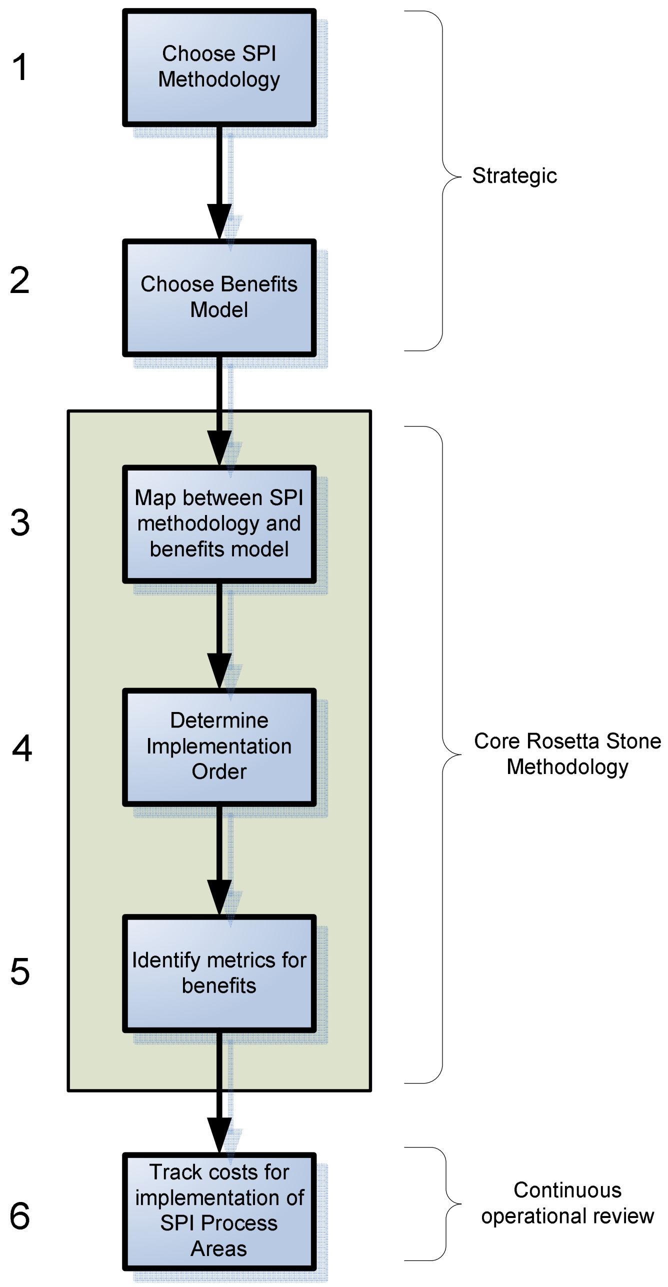

Figure 4-4: Rosetta Stone Methodology

4.3.1 Step 1 – Choose the SPI Methodology

As we have seen in Chapter 2, there are several SPI models and methodologies currently in use within ICT and several factors influence an organization's decision on which SPI methodology to use. The first category of factors revolve around the reason an organization chooses to implement Software Process Improvement in the first place. While many organizations choose to implement SPI purely to improve their software process, others may have one or other of the following reasons for implementation:

- Required. In many situations, organizations may be forced to implement a particular SPI methodology just in order to compete in their chosen market. For example, in order to compete for many US Department of Defense contracts, suppliers may be required to have a certain CMM or CMMI maturity level. The same also hold true for other areas such as pharmaceuticals or medical devices.
- Business Enabler. Unlike in the previous situation where attainment of a certain level of maturity is a minimum requirement to gain entry to a market, attainment of a certain level of maturity can put an organization at an advantage in relation to its competitors. In recent years, for example, with the advent of the off-shoring development model, many Indian consulting firms such as Wipro Technologies and Tata Consulting Services, spent their energies on attaining certifications in order to gain a market advantage over their competitors and now use this as a market differentiator. In addition, based on the RS-ICMMI validation interviews, there have been at least 2 cases in Ireland where local IT organizations gained certifications as a means to justify their desire to take on more responsibilities within their parent organizations.

Having determined that implementation of SPI is necessary, the focus then moves on to which SPI methodology to use. For this decision, the target industry is a major factor in deciding which SPI to implement. Certain SPI methodologies are geared towards certain industries. For example MediSPICE (McCaffery and Dorling 2009) is geared toward the medical industry while Trillium (Coallier 1994; 1995) is geared towards the communications industry.

4.3.2 Step 2 – Choose the Benefits Model

Different organizations have different organizational goals and missions. Many of the organizations we are most familiar with are for-profit organizations such as IBM, Microsoft, and Oracle. The aim of these organizations is to increase shareholder wealth and they typically do this by increasing profit which is done by maximizing revenue and minimizing costs. On the other hand, many organizations are not-for-profit organizations whose aim is to further their non-profit goals and objectives. Again, we are familiar with many of these organizations – universities, government bodies, and charities are examples of the not-for-profit organizations that we are exposed to on a daily basis. What both the for-profit and not-for-profit organizations have in common, however, is that both types of organization try to use their use their resources most efficiently to achieve their organizational objectives.

To support these objectives, IBM Global Services in India have developed a general purpose unified business objectives model. The ultimate objective of this benefits model is to increase revenues and, as such, is therefore more suited as a benefits model for for-profit organizations rather than not-for-profit organizations.

However, with a small number of changes, this model could be altered to accommodate various different final/ultimate objectives such as Safety or Quality (for organizations such as NASA) or Efficiency for charitable organizations such as the Red Cross or Doctors Without Frontiers.

4.3.3 Steps 3 - Mapping between the SPI Methodology and the Benefits model

One of the core questions within this research work is how do we determine the benefits associated with the implementation of a Process Area? This is done by creating a mapping between Goals (Business Objectives) and Questions (Process Areas) using the modified GQM model described earlier but doing so using a *reverse mapping* between Process Areas (Questions) and Business Objectives (Goals). This process is graphically illustrated in Figure 4-5 and Figure 4-6 using the modified GQM model described in section 3.7 as a template.

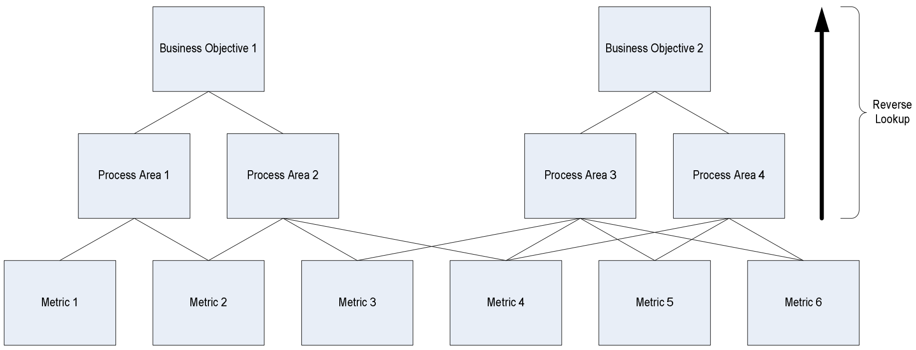

Figure 4-5: Modified GQM Reverse Lookup

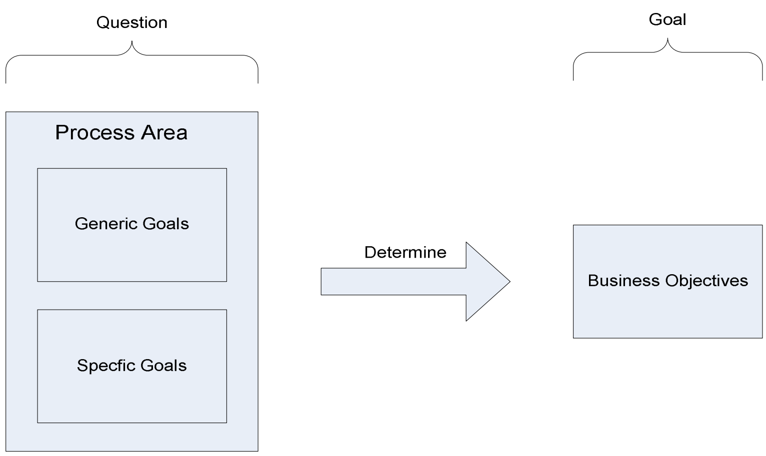

Figure 4-6: PA to Business Objective Map using a reverse GQM map

4.3.4 Step 4 – Determine Implementation Order

One of the primary objectives of the Rosetta Stone Methodology is to allow organizations to achieve specific, targeted business objectives or benefits by implementing specific Process Areas. This step in the process is the step which allows us to determine which Process Areas should be implemented, and in what order, to achieve those specific business benefits. In addition to the 2 previous steps, a prerequisite for this step is an understanding of what business objectives an organization wishes to achieve. This understanding may come from many sources – for example, a Six Sigma review of existing business processes, feedback from clients, or even input from internal sources such as the IT or Finance departments. Given that an organization knows what business objectives it wishes to achieve, it must then use the map which was built up in Step 3 to determine which Process Areas contribute to the desired business objective. An implementation order is then built up to determine in which order Process Areas should be implemented. From the Rosetta Stone Methodology perspective, we differentiate between primary and secondary benefits – in other words, the impact a Process Area has on a benefit. All things being equal, therefore, Process Areas which contribute to a business objective in a primary capacity should be implemented first as they have a greater impact on a business objective than a secondary capacity. Finally, depending on the SPI methodology chosen, there may be some inherent ordering within the methodology which must be taken into account. For example, the CMMI (Staged) methodology has the concept of maturity levels where each level is dependent upon previous levels. As a result, Process Areas at lower levels should be implemented before Process Areas at higher levels.

4.3.5 Step 5 – Identification of Metrics/Indicators for Benefits

As a result of implementing step 4, upon entering this step an organization knows which business objectives it wishes to achieve. Each potential benefit must be capable of being monitored in order to determine if the benefit is being received by the organization or not. GQM (Basili and Weiss 1984; Basili and Rombach 1988; Basili 1992; Basili et al. 1994) is a well-established methodology for defining measurable goals and has been used to establish successful measurement programs in industry. According to Basili, the GQM process is composed of 5 distinct steps:

1. Develop a set of Goals for productivity and quality
2. Generate Questions that define the Goals in a quantifiable way
3. Specify the metrics required to answer the Questions
4. Develop mechanisms for data collection
5. Collect, validate, and analyse the data.

The first 3 steps are graphically illustrated in Figure 4-7. Specifically with regard to the Rosetta Stone Methodology, each Goal is the analysis of a particular Benefit from the Benefits model. The Question is “what are the objective measures which can be used to determine if a benefit is being achieved", with Metrics defining what is to be measured.

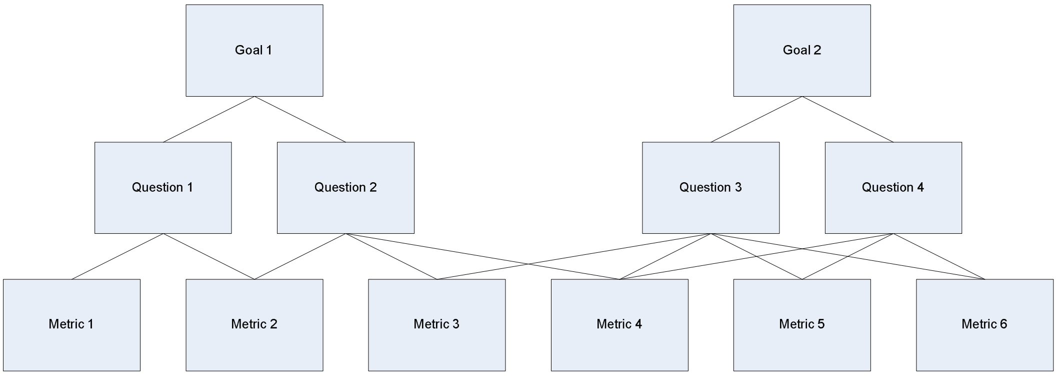

Figure 4-7: Traditional GQM Approach (Basili, 1992)

Step 6 - Tracking of Costs and Returns

The final step involves tracking both the Costs and the Returns and is operational in nature as this step will typically be performed by the front-line staff involved in developing software such as the Project Management Office, the development staff, and the Quality Assurance staff. Note that, as this step has not been implemented as part of this work, this step will not be discussed in the section on operationalization.

4.4 Operationalization of the Rosetta Stone Methodology

The Rosetta Stone IGSI-ISM to CMMI Instance mapping (RS-ICMMI) brings together a well-defined and extensible hierarchical set of benefits that is applicable to most commercial organizations, a mapping of the benefits of CMMI Process Areas to these benefits, and an industry-standard set of metrics that are indicators of the benefits defined in the model. In addition, users of the instance are free to add any pre-existing, custom, or about-to-be-measured metrics that they may have, thus allowing them to re-use any existing work that they may already have undertaken or are about to undertake. Having discussed the methodology at a high level, this section now deals with how to operationalize the methodology. The first two tasks are to decide on which SPI methodology to use and which benefits model to use.

4.4.1 Step 1 - Choose SPI Methodology – CMMI (Staged)

As discussed in Chapter 2, there are several widely used SPI methodologies currently in use in the field of ICT. The choice of which one to use is up to the individual organizations. However, in order to demonstrate how to operationalize RSM, I have chosen the SEI's CMMI (Staged) methodology as the demonstration SPI. It was chosen primarily as it is one of the most popular SPI methodologies in use today and is therefore widely understood and used by many practitioners. However, as discussed earlier, there are several other SPI methodologies currently in use, some of which may be more suited to a particular industry or geographic region. For example, Automotive SPICE is a software process assessment standard based on ISO/IEC 15504 for use within the automobile industry and CMMI, while used around the world, is particularly used by organizations who develop software for the American Department of Defense.

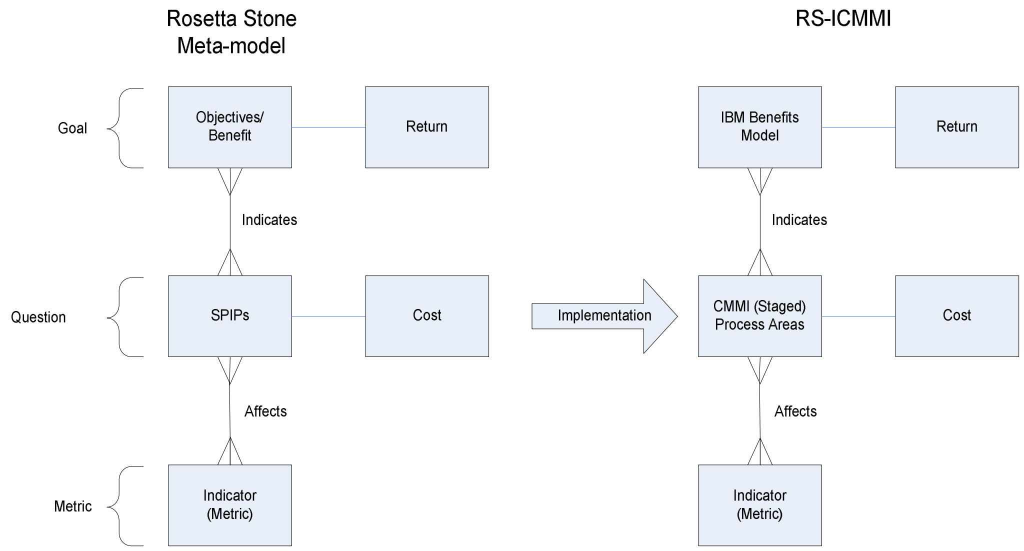

Figure 4-8: Implementation Instance of RS-ICMMI

4.4.2 Step 2 – Choose Benefits Model – IGSI-ISM Benefits Model

As professionals, we are concerned with trying to determine the costs and benefits across many projects within many organizations, industries, and countries and want to be able to categorize individual benefits as a way to model, aggregate, and develop a shared view of them across the various SPI processes that we are studying. To that end, I will use a model developed by Goyal et al. (2001), referred to as the IGSI-ISM model (IGSI-ISM model). The model is a generic for-profit benefits model, with the ultimate goal being an increase in revenues/profits, and which will appeal to a broad spectrum of for-profit organizations. As part of research undertaken on the benefits of SPI for IBM Global Services, India (IGSI), two workshops were held using consensus-based responses as inputs for an Interpretive Structural Modelling (ISM) methodology that was then used to develop a model of the needs and consequences of SPI. The IGSI-ISM model (see Figure 4-9) shows the relationships between the various benefits that can be derived from SPI. Using this model, there are 21 separate identifiable benefit areas.

The IGSI-ISM model has several benefits. Firstly, it is a for-profit model, and therefore appeals to a large amount of organizations whose primary purpose is to generate profits for their owners/shareholders. It is also a hierarchical model which allows benefits to be derived from other benefits. From a practitioner's perspective, it is important to realize that, in achieving specific benefits, you may also achieve other, secondary benefits and it may be useful to bear those relationships in mind when deciding which benefits to pursue. The particular benefits/objectives identified in the model are also high-level enough to identify achievable objectives while at the same time low-level enough to satisfy most organizations. However, no one model will satisfy everyone's needs and, even while this model is a good, overall benefits/objectives model, there are still those organizations who are not-for-profit organizations or who wish to focus on objectives which are not included in this model.

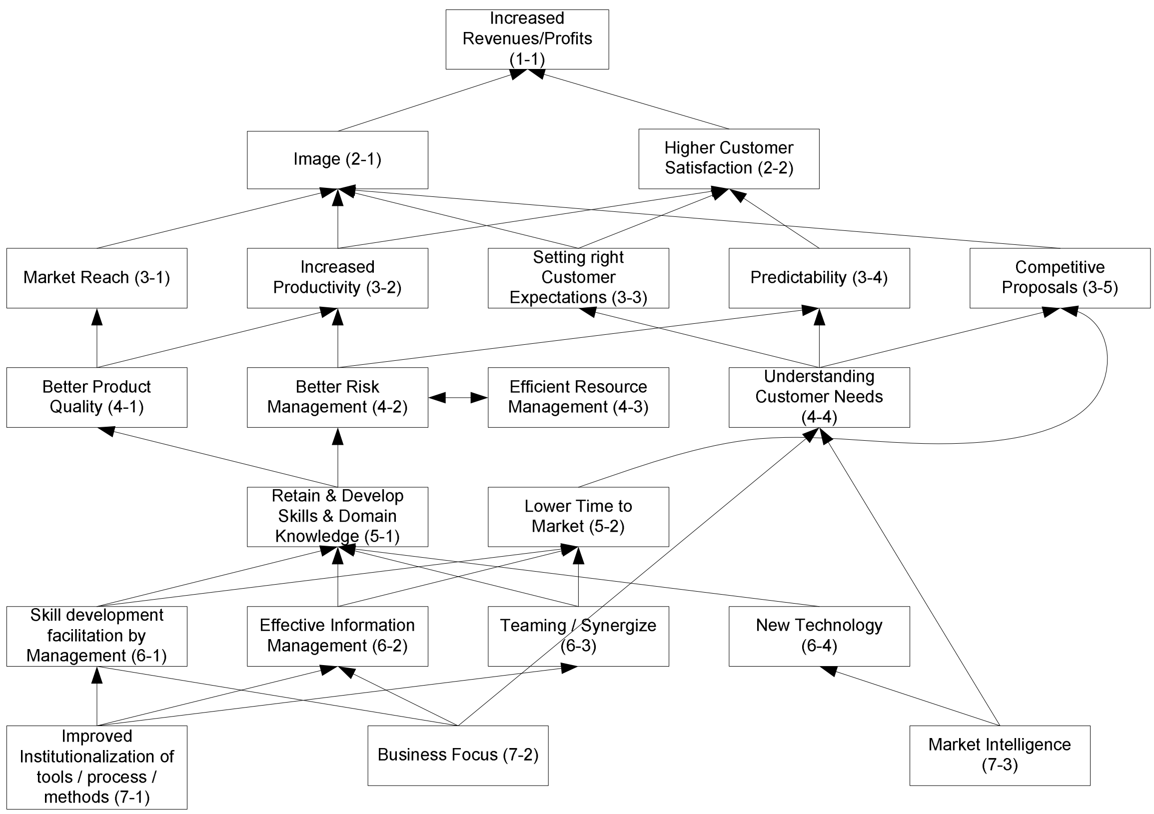

Figure 4-9: IGSI-ISM ROI Model (Goyal et al., 2001)

Unfortunately, I was unable to establish the definitions of all the benefits from relevant publications. Therefore, for consistency and uniformity in this work, I have interpreted the meanings in a specific way. These meanings are defined in Table 4-1.

It should be noted that the model is a hierarchy of benefits – higher level benefits are derived from elements that are lower in the benefit tree. For example, if the quality of code can be improved ("Better Product Quality", 4-1), this leads to increased productivity ("Increased Productivity", 3-2). Similarly, increasing the understanding of customer needs ("Understanding Customer Needs", 4-4) leads to being able to more accurately setting customer expectations ("Setting right customer expectations", 3-3) and thus increased predictability ("Predictability", 3-4) and to more competitive proposals ("Competitive Proposals", 3-5). To bring the traceability to its ultimate conclusion, it should be apparent that 3-2, 3-3, and 3-4 lead to better image ("Image", 2-1) and greater customer satisfaction ("Increased Customer Satisfaction", 2-2) which both in turn lead to more profits and revenue ("Increased Profits/Revenue", 1-1).

Risk Management ("Better Risk Management", 4-2) is another example which highlights the usefulness of a hierarchical model. If strategies are undertaken which provide better ways to manage risk, factors which increase instability are reduced and thus there is a corresponding increase in predictability in projects ("Predictability", 3-4). In addition, by taking away or reducing risk we decrease the amount of effort spent doing unnecessary tasks and thus increase productivity ("Increased Productivity", 3-2). To follow this farther up the tree, we see that both "Increased Productivity" and "Predictability" lead to a better image ("Image", 2-1) and greater customer satisfaction ("Higher Customer Satisfaction", 2-2) which in turn leads to our ultimate objective – increased profits ("Increased Revenue/Profits", 1-1).

For the purposes of this thesis, benefits that come about as a consequence of other benefits are called "derived" benefits and are discussed in detail in section 4.4.3.

The relationships between the various benefits which are graphically modelled in Figure 4-9 are listed below in Table 4-1. In the model, relationships from a benefit that resides on a lower in the diagram to one that is higher up are "leads to" relationships. For example, Higher Customer Satisfaction (level 2, label 2-2) "leads to" Increased Revenues/Profits.

Identifier	Benefit	Description
1-1	Increased Revenues/Profits	The increase of revenue and/or profits to the benefit of the organization
2-1	(Increased) Image	The creation of a better image of the organization both externally and internally within the organization
2-2	Higher Customer Satisfaction	An increase in customer satisfaction of an organization's product or service
3-1	(Better) Market Reach	An increase the market reach of the organization
3-2	Increased Productivity	An increase product productivity
3-3	Setting right Customer Expectations	Ensuring that customer expectations are in line with product delivery
3-4	(Increased) Predictability	Products are consistently delivered within expected thresholds
3-5	(More) Competitive Proposals	Product proposals are competitive. Note that competitiveness is not necessarily solely about financials. Competitiveness can also involve ensuring that proposals meet regulatory or other customer-/client-specific requirements.
4-1	Better Quality Product	Products are delivered to good quality standards.
4-2	Better Management Risk	Risk is managed and monitored in a proactive manner.
4-3	(More) Efficient Resource Management	Organization resources are managed in an efficient manner. Resources include, but are not limited to, financial, human, process, and technical resources and assets.
4-4	(Better) Understanding Customer Needs	Customer/client needs are understood and acted upon
5-1	Retain & Develop Skills & Domain Knowledge	Retain and develop skills and process as well as domain knowledge.
5-2	Lower Time to Market	Reduce product time to market.
6-1	(Increase) Skill Development Facilitation by Management	Organization actively ensures employees' skills are in sync with the technical and domain areas which are the subject of the products being developed/serviced by the organization.
6-2	(More) Efficient Information Management	Information is efficiently managed throughout the organization, including product teams allowing the organization to dynamically and quickly change based on the information provided.
6-3	(Increased) Teaming /	Organization structures are organized to work to

Identifier	Benefit	Description
	Synergize	maximize efficiencies within teams.
6-4	(Introduction) New Technology	New technology is used in an appropriate manner to aid the organizations objectives.
7-1	Improved Institutionalization of tools / process / methods	Tools/process/methods are institutionalized to provide organizational benefit.
7-2	(Better) Business Focus	Allows the organization to focus on its business, not on the tools, technologies, and techniques used to develop its products.
7-3	(Increased) Market Intelligence	Allows the organization to acquire market intelligence on the markets in which it operates.

Table 4-1: IGSI-ISM Benefits

4.4.3 Step 3 – Map between SPI Methodology and Benefits Model

This next step is at the core of the methodology. It requires someone to define all the mappings between the chosen SPI methodology and the chosen benefits model and all subsequent steps depend on the accuracy of the mapping. To arrive at the mapping, I iteratively reviewed each PA and its associated GGs, SGs, and SPs, with (SEI 2002b) as the reference document, to determine which ones have particular relevance to the IGSI-ISM benefit model (see Figure 4-9) using the modified GQM model discussed in section 3.7. In effect, the reverse lookup asks "What objectives does this question answer?" In terms of the RS-ICMMI model, the reverse lookup asks "What objectives does this PA answer?"

Not all benefits are equal and the model differentiates between primary and secondary benefits. A *primary* benefit of a Process Area is one that is brought about as a direct result of implementation of a process area where the cause and effect relationship between the Process Area implementation and the benefit is very strong. *Secondary* benefits are those benefits which are not primary benefits or are *derived* benefits. A *Derived* benefit is a benefit which is a hierarchical ancestor of either a primary or secondary benefit.

As a demonstration of how the mapping was created the following sections show, for each CMMI Level 2 Process Area, which GGs, SGs, and SPs are relevant for which expected benefits and why. The results of this mapping are detailed in Table 4-2 and a full mapping is detailed in Appendix A. To put this in the context of the modified GQM approach, each sub-section below is an iteration through all the PAs in CMMI Level 2 (with each PA being the "Question") and the Expected Benefits within each sub-section being the "Goal/Business Objectives" that the "Question" answers.

Process Area	**Abbr.**	**Expected Primary Benefits**
Configuration Management	CM	Better Quality Product
Configuration Management	CM	Better Risk Management
Configuration Management	CM	Teaming/Synergize
Measurement and Analysis	MA	Better Quality Product
Measurement and Analysis	MA	Better Risk Management
Measurement and Analysis	MA	Lower Time to Market
Measurement and Analysis	MA	Predictability
Project Monitoring and Control	PMC	Better Quality Product
Project Monitoring and Control	PMC	Better Risk Management
Project Monitoring and Control	PMC	Efficient Resource Management
Project Monitoring and Control	PMC	Setting Right Customer Expectations
Project Monitoring and Control	PMC	Predictability
Project Planning	PP	Better Quality Product
Project Planning	PP	Better Risk Management
Project Planning	PP	Efficient Resource Management
Project Planning	PP	Understanding Customer Needs
Project Planning	PP	Setting Right Customer Expectations
Project Planning	PP	Predictability
Project Planning	PP	Competitive Proposals
Process and Product Quality Assurance	PPQA	Better Quality Product
Process and Product Quality Assurance	PPQA	Better Risk Management
Process and Product Quality Assurance	PPQA	Lower Time to Market
Process and Product Quality Assurance	PPQA	Improved Institutionalization of Tools/Process/Methods
Process and Product Quality Assurance	PPQA	Predictability
Requirements Management	REQM	Better Risk Management
Requirements Management	REQM	Understanding Customer Needs
Requirements Management	REQM	Lower Time to Market
Supplier Agreement Management	SAM	Better Quality Product
Supplier Agreement Management	SAM	Better Risk Management

Process Area	Abbr.	Expected Primary Benefits
Supplier Agreement Management	SAM	Predictability
Supplier Agreement Management	SAM	Lower Time to Market

Table 4-2: : CMMI (Staged) Level 2 to IGSI-ISM Map – Primary Benefits

Requirements Management (REQM)

The purpose of Requirements Management (REQM) is to manage the requirements of the project's products and product components and to identify inconsistencies between those requirements and the project's plans and work products (SEI 2002b; Chrissis et al. 2003).

The REQM Process Area (PA) contains 1 Specific Goal (SG) which in turn consists of 5 Specific Practices (SP). The goal of SG1 is that "requirements are managed and inconsistencies with project plans and work products are indentified." Specifically, the project maintains a current approved set of requirements over the life of the project by doing the following (SEI 2002b):

- Managing all changes to the requirements
- Maintaining the relationships among the requirements, the project plans, and the work products
- Identifying the inconsistencies among the requirements, the project plans and the work products
- Taking corrective action

In particular, REQM requires the implementation of the obtaining of an understanding of requirements (SP 1.1-1), the obtaining of a commitment to requirements (SP 1.2-2), the management of requirements (SP 1.3-1), and the identification of inconsistencies between project work and requirements. These directly lead to expected benefits. Expected primary benefits for REQM are shown in Table 4-3 and expected secondary, non-derived benefits are shown in Table 4-4.

Obtaining the derived benefits is a well-defined process performed by walking the IGSI-ISM benefits tree. This section discusses REQM while the remaining Level 2 areas will be discussed next. As it is a well-defined process and does not require any specific insight, the remaining discussion on each Level 2 Process Area will concentrate on the reasons behind the primary and non-derived secondary mappings and will only note the derived benefits as part of the summary section. The format for each remaining Process Area will be as follows:

1. The expected primary benefits resulting from the implementation of a Process Area and the reasons why they are the expected primary benefits

2. The expected secondary, non-derived benefits resulting from the implementation of a Process Area and the reasons why they are the expected secondary, non-derived benefits
3. A summary table consisting of the expected primary and secondary benefits resulting from the implementation of a Process Area.

Benefit	Reason
Better Risk Management (4-2)	By managing requirements and identifying inconsistencies, we are better able to identify alternative strategies and avoid building software that isn't part of a customer's requirements. In addition, inconsistencies are identified up front.
Understanding Customer Needs (4-4)	Proper management of requirements forces us to consistently review those requirements and thus focus on understanding customer needs. By identifying inconsistencies between requirements, plans, and work products we are constantly ensuring that the customer's needs are always foremost.
Lower Time to Market (5-2)	By identifying inconsistencies up front, we will spend less time working on items that are not required by customers or that are inconsistent with customers' needs and expectations. As a result, less time will be spent on rework, thus saving resources and reducing time to market.

Table 4-3: Expected primary benefits of REQM

Expected Secondary Benefit	Reason
Market Intelligence (7-3)	Constant requirements review and management will ensure organizations are familiar with the requirements needed for systems in the chosen domain area. This in turn may lead to increased market intelligence in that domain.
Retain & Develop Skills and Domain Knowledge (5-1)	By constantly ensuring that requirements are in line with various project work products, organizations are constantly reviewing the applicability of their resources to the work products and resources required. This will then help them in developing and retaining domain knowledge.
Efficient Resource Management (4-3)	By constantly ensuring that requirements are in line with project plans and work products, organizations are forced to review the resource profiles

Table 4-4: Expected secondary, non-derived benefits of REQM

One of the advantages of using the IGSI-ISM benefits model is that there are relationships between benefits where achieving one particular benefit contributes to the achievement of some other benefit(s). These benefits may then in turn lead to other benefits and so forth. In graph theory terms, the benefits model may be regarded as a tree and the derived benefits are mapped by traversing the tree from lowest node to highest. Using this approach, the benefits resulting from implementation of REQM (Table 4-3 and Table 4-4) will contribute to the derived benefits defined in Table 4-5.

Benefit	**Leads To**
Better Risk Management (4-2)	Better Risk Management (4-2) leads to Increased Productivity (3-2) and Predictability (3-4). Increased Productivity (3-2) leads to a better Image (2-1) and Higher Customer Satisfaction (2-2). Predictability (3-4) leads to Higher Customer Satisfaction (2-2). Better Image (2-1) leads to Increased Revenues/Profits (1-1). Higher Customer Satisfaction leads to Increased Revenues/Profits (1-1).
Efficient Resource Management (4-3)	Efficient Resource Management (4-3) leads to Better Risk Management (4-2). Better Risk Management (4-2) leads Increased Productivity (3-2) and Predictability (3-4). Increased Productivity (3-2) leads to a better Image (2-1) and Higher Customer Satisfaction (2-2). Predictability (3-4) leads to Higher Customer Satisfaction (2-2). Better Image (2-1) leads to Increased Revenues/Profits (1-1). Higher Customer Satisfaction leads to Increased Revenues/Profits (1-1).
Understanding Customer Needs (4-4)	Understanding Customer Needs (4-4) leads to Setting Right Customer Expectations (3-3), increased Predictability (3-4), and more Competitive Proposals (3-5). Setting Right Customer Expectations (3-3) leads to a better Image (2-1) and Higher Customer Satisfaction (2-2). Predictability (3-4) leads to Higher Customer Satisfaction (2-2). Competitive Proposals (3-5) leads to increased Image (2-1). Better Image (2-1) leads to Increased Revenues/Profits (1-1). Higher Customer Satisfaction leads to Increased Revenues/Profits (1-1).
Retain & Develop Skills and Domain Knowledge (5-1)	Retain & Develop Skills and Domain Knowledge (5-1) leads to Better Risk Management (4-2) and Better Quality Product (4-1). Better Quality Product (4-1) leads to increased Market Reach (3-1) and Increased Productivity (4-2). Increased Market Reach (3-1) leads to increased Image (2-1) and increase Image (2-1) leads to Increased Revenues/Profits (1-1). Better Risk Management (4-2) leads to Increased Productivity (3-2) and Predictability (3-4). Increased Productivity (3-2) leads to a better Image (2-1) and Higher Customer Satisfaction (2-2). Predictability (3-4) leads to Higher Customer Satisfaction (2-2). Better Image (2-1) leads to Increased Revenues/Profits (1-1). Higher Customer Satisfaction leads to Increased Revenues/Profits (1-1).
Lower Time to Market (5-2)	Lower Time to Market (5-2) leads to Competitive Proposals (3-5). Competitive

Benefit	Leads To
	Proposals (3-5) leads to better Image (2-1). Better Image (2-1) leads to Increased Revenues/Profits (1-1).
Market Intelligence (7-3)	Increased Market intelligence (7-3) leads to New Technology (6-4) and an increased Understanding (of) Customer Needs (4-4). New Technology (6-4) leads to Retain & Develop Skills and Domain Knowledge (5-1). Retain & Develop Skills and Domain Knowledge (5-1) leads to Better Risk Management (4-2) and Better Quality Product (4-1). Better Quality Product (4-1) leads to increased Market Reach (3-1) and Increased Productivity (4-2). Increased Market Reach (3-1) leads to increased Image (2-1) and increase Image (2-1) leads to Increased Revenues/Profits (1-1). Better Risk Management (4-2) leads to Increased Productivity (3-2) and Predictability (3-4). Increased Productivity (3-2) leads to a better Image (2-1) and Higher Customer Satisfaction (2-2). Predictability (3-4) leads to Higher Customer Satisfaction (2-2). Better Image (2-1) leads to Increased Revenues/Profits (1-1). Higher Customer Satisfaction leads to Increased Revenues/Profits (1-1).

Table 4-5: Derived benefits of implementation of REQM

Project Planning (PP)

The purpose of Project Planning (PP) is to establish and maintain plans that define project activities and involves developing the project plan, interacting with stakeholders appropriately, getting commitment to the plan, and maintaining the plan (SEI 2002b). Of particular relevance to the IGSI-ISM model are SPs to identify project risks (SP 2.2-1), plan for needed knowledge and skills (SP 2.5-1), reconciliation of work and resource levels (SP 3.2-1), establishment of budget and schedule (SP 2.1-1), planning of stakeholder involvement (SP 2.6-1), and the obtaining of plan commitment (SP 2.7-1). In addition, the implementation of Generic Goal 2 (GG) to institutionalize a Managed Process aids in the predictability and quality of the product through a managed Project Planning process. Expected primary benefits for PP are shown in Table 4-6 and expected secondary benefits are shown in Table 4-7.

Benefit	Reason
Better Quality Product (4-1)	Project planning allows us to take a holistic view of a project and thoroughly plan all the various aspects that make up a quality end product. While it is not impossible to do this if a project is managed in piecemeal fashion, it certainly makes it much more likely with proper project planning.
Better Risk Management (4-2)	By planning the entire project up front, we can identify potential risks and plan accordingly.

Benefit	**Reason**
Efficient Resource Management (4-3)	By taking a holistic view of the project, we can identify all resource needs up front and make appropriate resourcing provisions.
Understanding Customer Needs (4-4)	A project plan will allow us to ensure that we are allocating sufficient resources (at a high level) to meet and interact with customers.
Setting Right Customer Expectations (3-3)	A project plan will allow us to estimate the relevant costs and duration of a project. This will help us set customer expectations.
Predictability (3-4)	Thoroughly planning and reviewing a project will allow us to predict how much effort and what resources are required for the project. In addition, by maintaining the project plan (especially with the help of quantitative management techniques), we will be able to become more accurate in our predictions over time.
Competitive Proposals (3-5)	Increased predictability will allow us to more accurately cost potential projects thus allowing us to come up with more competitive proposals.

Table 4-6: Expected primary benefits of PP

Benefit	Reason
Competitive Proposals (3-5)	Increased predictability will allow us to more accurately cost potential projects thus allowing us to come up with more competitive proposals.
Market Reach (3-1)	Stakeholder involvement is an essential part of PP. By involving itself on an on-going basis with stakeholders and performing in an efficient manner, organizations may be able to influence stakeholders in a positive way and thus increase market reach.
Increased Productivity (3-2)	The primary purpose of PP is to establish and maintain plans that define project activities. Unless a project is planned properly, there is no way for an organization to proactively manager resources on a project. If an organization does manage resources efficiently, this should translate into increased productivity.
Competitive Proposals (3-5)	Project Planning can aid in efficiently managing resources. If organizations can consistently manage their resources efficiently, thus increasing predictability, this will lead to competitive proposals as the risk of unpredictability in project costs can be significantly reduced.

Table 4-7: Expected non-derived secondary benefits of PP

Project Planning (PP)	
Expected Primary Benefits	**Expected Secondary Benefits**
• Better Quality Product (4-1) • Better Risk Management (4-2) • Predictability (3-4) • Setting Right Customer Expectations (3-3) • Competitive Proposals (3-5) • Efficient Resource Management (4-3) • Understanding Customer Needs (4-4)	• Market Reach (3-1) • Increased Productivity (3-2) • Competitive Proposals (3-5) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)

Table 4-8: Expected benefits of PP

Project Monitoring and Control (PMC)

The purpose of Project Monitoring and Control (PMC) is to provide an understanding of the project's progress so that the appropriate corrective actions can be taken when the project's performance deviates from the plan (SEI 2002b). In effect, PMC is the process whereby an organization monitors its project activities as described in PP and makes appropriate changes. This directly contributes to a better quality product, better risk management, more efficient resource management, increased predictability over time, and setting customer expectations during a project. In particular, PMC consists of two SGs which in turn consist of several SPs, some of which directly contribute to the expected benefits described in the next section. Those SPs are the monitoring of project planning parameters (SP 1.1-1), the monitoring of commitments (SP 1.2-1), the monitoring of project risks (SP 1.3-1), the monitoring of stakeholder involvement, including customer involvement (SP 1.5-1) and the conducting of progress and milestone reviews (SP 1.6-1/7-1). Expected primary benefits for PMC are shown in Table 4-9 and there are no expected non-derived secondary benefits of PMC.

Benefit	Reason
Better Quality Product (4-1)	The primary purpose of PMC is to provide an understanding of a project's progress to corrective actions can be undertaken. Such corrective action will allow action to be taken if the quality gates in a project plan are failing to be met.
Better Risk Management (4-2)	By constantly reviewing the progress of a project, a team is better able to manage and remediate any risks which arise.
Efficient Resource Management (4-3)	As a result of the constant review of progress, an organization can more allocate resources to those areas which need them and less to those areas which are making good progress.
Setting Right Customer Expectations (3-3)	In order to set the right customer expectations, project teams should proactively inform them of any changes or potential for change. It is always better to warn a customer of potential delays up front rather than waiting until the end to let them know of an actual delay. Actively monitoring the status of a project allows organizations to do just this.

Benefit	Reason
Predictability (3-4)	By actively monitoring projects, organizations are able to more accurately predict future projects and build those predictions into project plans.

Table 4-9: Expected primary benefits of PMC

By quantifying and monitoring project progress, we avoid getting into a crunch situation where people are under pressure to push untested or inadequately tested code to production. This also allows the project manager to re-allocate appropriate resources up front before the project goes into a tailspin. Consistent monitoring of projects across an organization will provide feedback to project managers as they are creating their project plans, thus increasing predictability and setting right customer expectations. In addition, as management and control functions are in place, project managers are in a position to know which parts of a project are particularly at risk and make appropriate choices and backup plans.

Project Monitoring and Control (PMC)	
Expected Primary Benefits	**Expected Secondary Benefits**
• Better Quality Product (4-1) • Better Risk Management (4-2) • Efficient Resource Management (4-3) • Setting Right Customer Expectations (3-3) • Predictability (3-4)	• Market Reach (3-1) • Increased Productivity (3-2) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)

Table 4-10: Expected benefits of PMC

Supplier Agreement Management (SAM)

The purpose of Supplier and Agreement Management (SAM) is to manage the acquisition of products from suppliers for which there exists a formal agreement (Chrissis et al. 2003). Reliance on an external supplier exposes an organization to quite a deal of risk and if that relationship is not handled correctly it can have disastrous consequences for an organization and a product. On the other hand, a top-notch external organization or product can greatly enhance an organization or product. The SAM PA consists of two SPs – the establishment of supplier agreements and the satisfying of supplier agreements. In particular SP 1.2-1 (select suppliers) and SP 1.3-1 (establish supplier agreements) allow an organization of specify Service Level Agreements (SLAs) that define quality and turnaround time on products as well as remediation and/or penalties if SLAs are breached. The expected primary benefits for SAM are detailed in Table 4-11 and the expected secondary, non-derived benefits of SAM are detailed in Table 4-12.

Benefit	Reason
Lower Time to Market (5-2)	One of the main benefits of SAM is the establishment of SLAs which define the quality and minimum turnaround time on products. While an SLA may not necessarily lower time to marker, the corollary may be true – by not having an SLA in place, time to market may in fact be increased.
Better Quality Product (4-1)	SAM requires SLAs on Quality to be defined in a supplier agreement. Again, while an SLA may not necessarily lead to a better quality product, the corollary may be true – the absence of an SLA may lead to a worse quality product.
Better Risk Management (4-2)	SLAs and associated penalties around missing SLAs supplier agreements are a very important risk control when dealing with external (or internal) suppliers. Thus having an SLA in place will lead to better risk management.
Predictability (3-4)	SLAs based on quality, cost, and time will increase the predictability of any product depending on a supplier as, if a supplier fails to meet an SLA, the supplier will be subject to the penalties outlined in the supplier agreement.

Table 4-11: Expected primary benefits of SAM

During the process of entering into formal agreements with various suppliers, the organization will put in place safeguards to ensure the products supplied will be of a certain quality, have to be delivered within a certain timeframe and may also detail the quality and makeup of the individual components within the product being supplied. As a result of this process and agreement, the product supplied will be of a defined quality and will be delivered within a specified timeframe. This will affect individual projects by increasing overall quality and predictability, as well as helping to manage risk. In addition, suppliers will have expertise in producing the product in question. This expertise should translate to a lower time to market for the individual product and, as a result, to the project as a whole.

Benefit	Reason
Setting Right Customer Expectations (3-3)	By having SAM in place, formal agreements and SLAs are established between a supplier and an organization. The agreements and SLAs are negotiated with the knowledge of what customer expectations currently are and thus aid in setting and maintaining the right customer expectations for the organization.

Table 4-12: Expected non-derived secondary benefits of SAM

Supplier Agreement Management (SAM)	
Expected Primary Benefits	**Expected Secondary Benefits**
• Lower Time To Market (5-2) • Better Quality Product (4-1) • Better Risk Management (4-2) • Predictability (3-4)	• Market Reach (3-1) • Increased Productivity (3-2) • Setting Right Customer Expectations (3-3) • Predictability (3-4) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)

Table 4-13: Expected benefits of SAM

Measurement and Analysis (MA)

Definition

The purpose of Measurement and Analysis (MA) is to develop and sustain a measurement capability that is used to support management information needs (Chrissis et al. 2003). MA consists of 2 SGs – the alignment of Measurement and Analysis activities (SG1) and the obligation to provide measurement results (SG2). Measurement and analysis of appropriate metrics is essential in order to provide feedback to an organization on the current and potential future state of a project. SG1 provides several important SPs to enable the benefits described below. In particular, it provides for the specification of metrics (SP 1.2-1), the specification of data collection and storage procedures (SP 1.3-1), and the specification of analysis procedures (SP 1.4-1). SG2 in general provides for the feedback loop to enable an organization to act on the results of the results obtained in SG1. The expected primary benefits for MA are detailed in Table 4-14 and the expected secondary, non-derived benefits of MA are detailed in Table 4-15.

Benefit	Reason
Lower Time to Market (5-2)	MA involves the creation and reporting of various metrics to support management information needs. Such metrics will allow a project team to review important information with regard to the progress of a project. This will allow a project team to adapt their strategies to most efficiently bring a project to market.
Better Quality Product (4-1)	Product metrics such as quality are a major factor in establishing the quality of a product. With such metrics, it is possible to alter processes and procedures to increase the quality of products.
Better Risk Management (4-2)	Without the ability to measure various facts, it would be virtually impossible to determine if a project is at risk. Once a project team is aware of a risk, only then can they remediate the risk. This MA provides a project team the ability to

Benefit	Reason
	better manage risk.
Predictability (3-4)	Predictability is gained when, over time, accurate measurements are taken of various aspects of projects. Only when accurate measures are available, is it possible to predict costs, times, and quality.

Table 4-14: Expected primary benefits of MA

By developing and maintaining a measurement capability within a project and organization, we will enable the organization to quantify various aspects of the whole development lifecycle. This will allow the organization to see where certain elements break down and do not live up to their full potential. As a result, the organization should be able to make appropriate changes to projects and processes to produce better quality products, better manage risk, lower time to market, and increase predictability.

Benefit	Reason
Setting Right Customer Expectations (3-3)	One of the most important factors in setting the right customer expectations is in ensuring predictability – a product should be ready when an organization says it should be ready. As mentioned in the section on primary benefits, one of the main elements in aiding predictability is the collection of metrics across various projects which will allow an organization to create an organizational metric database. This database will aid in increasing predictability and, as a result, help in setting the right customer expectations.

Table 4-15: Expected non-derived secondary benefits of MA

Measurement and Analysis (MA)	
Expected Primary Benefits	**Expected Secondary Benefits**
• Lower Time To Market (5-2) • Better Quality Product (4-1) • Better Risk Management (4-2) • Predictability (3-4)	• Market Reach (3-1) • Increased Productivity (3-2) • Setting Right Customer Expectations (3-3) • Competitive Proposals (3-5) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)

Table 4-16: Expected benefits of MA

Process and Product Quality Assurance (PPQA)

Definition

The purpose of Process and Product Quality Assurance (PPQA) is to provide staff and management with objective insight into processes and associated work products (SEI 2002b; Chrissis et al. 2003). This PA "supports the delivery of high quality products and services by providing the project staff and managers at all levels with appropriate visibility into, and feedback on, processes and associated work products throughout the life of the product." Increased quality has a direct relationship to product quality, risk reduction, lower time to market and, over time, increased predictability. Further, as per SP 1.2-1 (objectively evaluate work products and services), processes and methods are constantly under review and will result in improved institutionalization of successful processes and methods. The expected primary benefits for PPQA are detailed in Table 4-17. There are no expected secondary, non-derived benefits resulting from implementation of PPQA.

Benefit	Reason
Improved Institutionalization of Tools/Process/Methods (7-1)	One of the primary benefits of PPQA is to provide feedback on processes and associated work products throughout the life of a product. This feedback will allow organizations to alter how processes and work products are institutionalized which should aid in their adoption and institutionalizations.
Lower Time to Market (5-2)	Provision of feedback, in both the positive and negative, should provide opportunities to improve processes and thus lower time to market.
Better Quality Product (4-1)	Objective insight into processes and associated work products will allow improvements to be made in those processes and work products, thus increasing their quality and the quality of the product being produced.
Better Risk Management (4-2)	Improved processes should reduce an organization's risk by ensuring more robust and efficient processes and work products.
Predictability (3-4)	More improved and efficient processes in conjunction with better quality work products should increase the predictability of products being produced.

Table 4-17: Primary benefits of PPQA

The focus of this PA is on objectively evaluating performed processes, identifying non-compliance, and providing feedback on processes, including non-compliance issues. Doing so will lead to better quality products, and improved institutionalization of processes. In addition, by identifying non-compliant processes, overall risk will be lowered and predictability enhanced. A full review of processes should lead to optimization in processes and, as a result, lower time to market.

Process and Product Quality Assurance (PPQA)	
Expected Primary Benefits	**Expected Secondary Benefits**
• Improved Institutionalization of tools/process/methods (7-1) • Lower Time To Market (5-2) • Better Quality Product (4-1) • Better Risk Management (4-2) • Predictability (3-4)	• Skill development facilitation by management (6-1) • Effective Information Management (6-2) • Teaming/Synergize (6-3) • Retain & Develop Skills & Domain Knowledge (5-1) • Efficient Resource Management (4-3) • Understanding Customer Needs (4-4) • Market Reach (3-1) • Increased Productivity (3-2) • Setting Right Customer Expectations (3-3) • Predictability (3-4) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)

Table 4-18: Expected benefits of PPQA

Configuration Management (CM)

Definition

The purpose of Configuration Management (CM) is to establish and maintain the integrity of work products using configuration identification, configuration control, configuration status accounting, and configuration audits (SEI 2002b; Chrissis et al. 2003). CM consists of 3 SGs – SG1 (the establishment of baselines), SG2 (the tracking and control of changes), and SG3 (the establishment of integrity). In software projects it is absolutely essential that all artefacts are correctly baselined and tracked. Without this baselining and tracking, there is no guarantee that code, requirements or any other project artefact will be consistent with each other, thus increasing risk and reducing quality. In fact, the opposite is true, effective configuration management is essential for increasing quality and reducing risk. In addition, as Burzcuk and Appleton (2002) note, “configuration management, and in particular version control, plays a role in supporting to work of teams” and that “software configuration management serves as a mechanism for communication, change management and reproducibility.” The expected primary benefits for CM are detailed in Table 4-19 and the expected secondary, non-derived benefits of CM are detailed in Table 4-20Table 4-21.

Benefit	Reason

Teaming/Synergize (6-3)	Configuration Management is an essential process that allows project teams to efficiently share artefacts which in many cases should be modified by only one team member at a time. As such, it is a vital tool in teaming – allowing a team to work efficiently together.
Better Quality Product (4-1)	Configuration management is essential in ensuring that certain resources – such as source code – cannot be updated by multiple team members at once. As configuration management ensures that only the correct version of a work product may be worked on at any one time – integrity – this will lead to a better quality product.
Better Risk Management (4-2)	As a result of the integrity enforced by configuration Management, there is much less risk of work products being worked on out of sequence, thus minimizing a project team's exposure to risk as a result of integrity issues.

Table 4-19: Expected primary benefits of CM

Configuration management allows projects to properly track the various parts that make up their products. By instituting CM, multiple teams will be able to edit/modify code without stepping over each others' toes. In addition, CM allows project teams to map changes back to specific issues or requirements, thus increasing product quality and managing risk.

Benefit	Reason
Understanding Customer Needs (4-4)	Only by ensuring that all artefacts are correctly versioned can you ensure that you can understand and meet customer needs.

Table 4-20: Expected non-derived secondary benefits of CM

Configuration Management (CM)	
Expected Primary Benefits	**Expected Secondary Benefits**
• Teaming/Synergize (6-3) • Better Quality Product (4-1) • Better Risk Management (4-2)	• Retain & Develop Skills & Domain Knowledge (5-1) • Lower Time To Market (5-2) • Efficient Resource Management (4-3) • Understanding Customer Needs (4-4) • Market Reach (3-1) • Increased Productivity (3-2) • Setting Right Customer Expectations (3-3) • Predictability (3-4) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)

Table 4-21: Expected benefits of CM

Requirements Management (REQM)	
Expected Primary Benefits	**Expected Secondary Benefits**
• Better Risk Management (4-2) • Understanding Customer Needs (4-4) • Lower Time to Marker (5-2)	• Market Intelligence (7-3) • Retain & Develop Skills & Domain Knowledge (5-1) • Efficient Resource Management (4-3) • Predictability (3-4) • Competitive Proposals (3-5) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)
Project Planning (PP)	
Expected Primary Benefits	**Expected Secondary Benefits**
• Better Quality Product (4-1) • Better Risk Management (4-2) • Predictability (3-4) • Setting Right Customer Expectations (3-3) • Competitive Proposals (3-5) • Efficient Resource Management (4-3) • Understanding Customer Needs (4-4)	• Market Reach (3-1) • Increased Productivity (3-2) • Predictability (3-4) • Competitive Proposals (3-5) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)
Project Monitoring and Control (PMC)	
Expected Primary Benefits	**Expected Secondary Benefits**
• Better Quality Product (4-1) • Better Risk Management (4-2) • Efficient Resource Management (4-3) • Setting Right Customer Expectations (3-3) • Predictability (3-4)	• Market Reach (3-1) • Increased Productivity (3-2) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)
Supplier Agreement Management (SAM)	
Expected Primary Benefits	**Expected Secondary Benefits**
• Lower Time To Market (5-2) • Better Quality Product (4-1) • Better Risk Management (4-2) • Predictability (3-4)	• Market Reach (3-1) • Increased Productivity (3-2) • Setting Right Customer Expectations (3-3) • Predictability (3-4) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)

Table 4-22: Summary of all CMMI (Staged) Level 2 Benefits

Table 4-22 and Table 4-23 summarize all the expected primary and secondary benefits resulting from the implementation of RS-ICMMI.

Measurement and Analysis (MA)	
Expected Primary Benefits	**Expected Secondary Benefits**
• Lower Time To Market (5-2) • Better Quality Product (4-1) • Better Risk Management (4-2) • Predictability (3-4)	• Market Reach (3-1) • Increased Productivity (3-2) • Setting Right Customer Expectations (3-3) • Predictability (3-4) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)
Process and Product Quality Assurance (PPQA)	
Expected Primary Benefits	**Expected Secondary Benefits**
• Improved Institutionalization of tools/process/methods (7-1) • Lower Time To Market (5-2) • Better Quality Product (4-1) • Better Risk Management (4-2) • Predictability (3-4)	• Skill development facilitation by management (6-1) • Effective Information Management (6-2) • Teaming/Synergize (6-3) • Retain & Develop Skills & Domain Knowledge (5-1) • Efficient Resource Management (4-3) • Understanding Customer Needs (4-4) • Market Reach (3-1) • Increased Productivity (3-2) • Setting Right Customer Expectations (3-3) • Predictability (3-4) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)
Configuration Management (CM)	
Expected Primary Benefits	**Expected Secondary Benefits**
• Teaming/Synergize (6-3) • Better Quality Product (4-1) • Better Risk Management (4-2)	• Retain & Develop Skills & Domain Knowledge (5-1) • Lower Time To Market (5-2) • Efficient Resource Management (4-3) • Understanding Customer Needs (4-4) • Market Reach (3-1) • Increased Productivity (3-2) • Setting Right Customer Expectations (3-3) • Predictability (3-4) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)

Table 4-23: Summary of all CMMI (Staged) Level 2 Benefits (cont.)

4.4.4 Step 4 – Determine Implementation Order

In many cases, organizations are not so much concerned with faithfully implementing all CMMI Levels or all PAs as they are with achieving specific results. In fact, many organizations are agnostic as to the actual SPI methodology used to deliver results as long as they are achieved within a mature and repeatable framework. Examples of specific results that organizations may want to achieve are increases in productivity and/or lower their time to market. This section will concentrate on providing an example of how to achieve specific objectives. The sample objective used here is Lower Time to Market.

The process to achieve this is as follows:

1. Determine which of the IGSI-ISM objectives that we wish to achieve
2. Using the IGSI-ISM model, determine which other objectives, if any, contribute to achieving our primary objective
3. Using the PA-Business Objectives map, establish which PAs contribute to both the primary and secondary objectives that we have determined in the previous two steps
4. Rank the PAs in order of relevance and implementation.

This is represented graphically in Figure 4-10.

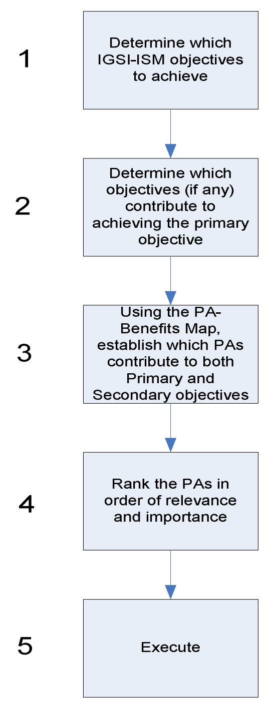

Figure 4-10: Determining order of implementation

Determine the IGSI-ISM Primary Objective

The choice of which IGSI-ISM objective to aim for is usually determined for us by outside forces such as senior management or, in some cases, external clients. The example used here is Lower Time to Market (5-2).

Determine IGSI-ISM objectives contribute to the Primary Objective

Using the IGSI-ISM model (Figure 4-9), it can be seen that Lower Time to Market (5-2) depends on the following lower-level objectives:

IGSI-ISM Id	Objective Name
6-1	Skill development Facilitation by Management
6-2	Effective Information Management
6-3	Teaming/Synergize
7-1	Improved Institutionalization of Tools/Process/Methods
7-2	Business Focus

Table 4-24: Lower Time to Market

Determine which PAs contribute to IGSI-ISM Objectives

To summarize our progress so far, we started out with a specific objective ("Lower Time to Market", 5-2), and then, using the IGSI-ISM model, we determined which lower-level objectives contribute to the higher level objective. Using Figure 4-9 and Table 4-22, PAs are identified as shown in Table 4-25.

PA Identifier	Staged Level	Process Area	Expected Primary IGSI ROI Benefits	Expected Secondary IGSI ROI Benefits
2-1	2 - Managed	Requirements Management	4-2, 4-4, 5-2	7-3, 5-1, 4-3, 3-4, 3-5, 2-1, 2-2, 1-1
2-4		Supplier Agreement Management	5-2, 4-1, 4-2, 3-4	3-1, 3-2, 3-3, 3-4, 2-1, 2-2, 1-1
2-5		Measurement and Analysis	5-2, 4-1, 4-2, 3-4	3-1, 3-2, 3-3, 3-4, 2-1, 2-2, 1-1
2-6		Process and Product Quality Assurance	7-1, 5-2, 4-1, 4-2, 3-4	6-1, 6-2, 6-3, 5-1, 5-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
2-7		Configuration Management	6-3, 4-2, 4-1	5-1, 5-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
3-1	3 - Defined	Requirements Development	5-2, 4-1, 4-2, 4-4,	4-3, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
3-6		Organizational Process Focus	7-1, 7-2, 7-3	6-1, 6-2, 6-3, 6-4, 5-1, 5-2, 4-1, 4-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
3-7		Organizational Process Definition	7-1, 6-2	6-1, 6-3, 5-1, 5-2, 4-1, 4-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
3-8		Organizational Training	6-1, 6-3	5-1, 5-2, 4-1, 4-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
		Integrated Project Management	6-3, 4-1, 4-2, 4-3, 4-4	5-1, 5-2, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
3-9		Integrated Project Management for IPPD	6-3, 4-1, 4-2, 4-3, 4-4	5-1, 5-2, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
3-11		Integrated Teaming	6-3, 6-2, 4-1, 4-3, 4-2, 4-4	5-1, 5-2, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
3-12		Integrated Supplier Management	7-2, 7-3, 6-3, 6-4, 5-2, 4-1, 4-2, 3-4	5-1, 5-2, 4-3, 3-1, 3-2, 3-3, 3-5, 2-1, 2-2, 1-1
3-14		Organizational Environment for Integration	7-1, 7-2, 6-2, 6-3, 5-2	6-1, 6-2, 6-4, 5-1, 5-2, 4-1, 4-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
4-1	4 - Quantitatively Managed	Organizational Process Performance	7-1, 7-2, 7-3, 6-2	6-1, 6-3, 5-1, 5-2, 4-1, 4-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
4-2		Quantitative Project Management	5-2, 4-1, 4-2, 4-3	4-3, 4-4, 2-1, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
5-1	5 - Optimizing	Organizational Innovation and Deployment	7-1, 7-2, 7-3	6-1, 6-2, 6-3, 6-4, 5-1, 5-2, 4-1, 4-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
5-2		Causal Analysis and Resolution	7-1, 6-2, 5-2, 4-1, 4-2, 4-3	6-1, 6-3, 5-1, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 3, 1-1

Table 4-25: Example Objective - Lower Time to Market

Rank Process Areas for Implementation

As can be seen from Table 4-25, there are several PAs which have an effect on Lower Time to Market. Most organizations have finite resources and so will not be able to implement them all concurrently so we are forced to prioritize them for implementation. There are many different ways to rank them but there are two very important factors to keep in mind when deciding on an order:

1. More consideration should be given to those PAs that primarily satisfy a particular objective. By this we mean that those PAs that satisfy an objective as a primary objective should be given higher ranking than those that do not. For example, in Table 4-25 we see that both Process and Product Quality Assurance (PPQA) and Configuration Management (CM) both help to us attain Lower Time to Market. PPQA has Lower Time to Market as a primary objective while CM does not. As a result, PPQA should be implemented before CM. The reasoning behind this is that PPQA fully satisfies the Lower Time to Market objective while CM satisfies the Teaming/Synergize (6-3) objective which is only a contributing objective to Lower Time to Market
2. More consideration should be given to those PAs that, in the Staged Model, are lower in the Stage phases. For example, both Requirements Management (RM) and Requirements Development (RD) directly satisfy Lower Time to Market but, as RM is a Level 2 PA, it should be undertaken before RD.

Using these principles, here would be a recommended order for implementation:

PA Identifier	Process Area	Expected Primary IGSI ROI Benefits
2-1	Requirements Management	4-2, 4-4, 5-2
2-4	Supplier Agreement Management	4-2, 4-1, 3-4, 5-2
2-5	Measurement and Analysis	4-2, 4-1, 5-2, 3-4
2-6	Process and Product Quality Assurance	4-1, 4-2, 5-2, 7-1, 3-4
3-1	Requirements Development	5-2, 4-4, 4-2, 4-1
3-12	Integrated Supplier Management	7-3, 6-3, 6-4, 4-1, 4-2, 7-2, 3-4, 5-2
3-14	Organizational Environment for Integration	6-2, 6-3, 7-2, 5-2, 7-1
4-2	Quantitative Project Management	4-1, 4-2, 4-3, 5-2
5-2	Causal Analysis and Resolution	6-2, 5-2, 4-1, 4-2, 4-3, 7-1
2-7	Configuration Management	6-3, 4-2, 4-1
3-6	Organizational Process Focus	7-1, 7-2, 7-3
3-7	Organizational Process Definition	6-2, 7-1

PA Identifier	Process Area	Expected Primary IGSI ROI Benefits
3-8	Organizational Training	6-1, 6-3
3-9	Integrated Project Management for IPPD	6-3, 4-1, 4-2, 4-3, 4-4
3-11	Integrated Teaming	6-3, 4-1, 4-3, 4-2, 4-4, 6-2
4-1	Organizational Process Performance	7-1, 7-2, 7-3, 6-2
5-1	Organizational Innovation and Deployment	7-1, 7-2, 7-3

Table 4-26: Implementation order of PAs

Note that this is *a* recommended order – there are other equally valid orders that could be undertaken depending on the requirements of the organization. Therefore, if it has been established by either a formal or an informal capability assessment that an organization is weaker in a particular PA than others, then it may make sense to prioritize that PA within the principles outlined above. Therefore, if an organization has been assessed as being relatively more mature in Requirements Management but less mature in Configuration Management, it may make sense to prioritize Configuration Management over Requirements Management.

4.4.5 Step 5 – Identify Metrics for Benefits

As explained in section 4.3, identification of which metrics may be used to determine if an organization is succeeding in achieving its business objectives is carried out using GQM. In this section, we shall take some specific examples of business objectives and determine appropriate metrics which can be used to determine if an organization is succeeding in achieving its business objectives. It should be noted (as shown in Figure 4-8) that there is a many-to-many relationship between a metric and a benefit i.e. a given metric may be associated with one or more benefits and a given benefit may be associated with one or more metrics. As a result, a metric may appear as an indicator for more than one benefit.

For the first example, we will take Lower Time to Market (5-2). A possible metric could be, for projects of a given complexity, the time to complete from concept to release. We could also investigate if, for the various parts of the project life cycle, durations have increased, decreased or remained static.

To measure the Better Quality Product (4-1), possible metrics include defect density at various phases in the lifecycle, costs due to lack of quality (Mandeville 1990; Houston and Keats 1996), loss of reputation to the firm, any lost bids, software reliability, software rate of change (Garmus and Herron 2001), or increase/decrease in software complexity (McCabe 1976; Halstead 1977).

Possible metrics to see progress on Better Risk Management (4-2) could be availability of risk and mitigation plans, the number of risk and mitigation points available, Requirements Risk Metrics (Nogueira et al. 2000) such as Birth Rate (BR – percentage of new requirements added in each cycle of the evolution process), Death Rate (DR – percentage of requirements dropped by client at each stage in the evolution process), Change Rate (CR – percentage of existing requirements changed at each stage of the process), and Risk Leverage (Christensen and Thayer 2001).

Measurement of Understanding Customer Needs (4-4) can be done qualitatively, using such metrics as requirements stability and customer satisfaction (Kan 2003):

- % completely satisfied
- % satisfied (satisfied and completely satisfied)
- % dissatisfied customers (dissatisfied and completely dissatisfied)
- % non-satisfied customers (neutral, dissatisfied, completely dissatisfied).

It should be noted that all the metrics mentioned above are illustrative of potential metrics that may be used to check on progress within an improvement program and are not exhaustive. One of the advantages of using the RS-ICMMI model is the fact that practitioners are free to use whatever metrics they deem to be most appropriate to measure progress within particular areas.

4.5 Conclusion

The power of the RSM model lies in the fact that it is a flexible and straight-forward methodology that can be readily and easily modified by practitioners to fit their own particular needs. Like ISO/IEC 15504 and CMMI, I describe a methodology and what it is capable of doing. In addition, I provide an implementation of the methodology. The power of RS-ICMMI instance is that it uses an industry-standard SPI model and is of immediate use by practitioners with little, if any, modification. By describing in abstract terms what a metric/indicator is, what a generic benefit/objective is, what an SPI is, and the relationships between them, the door is open for practitioners to use the model on whatever SPI initiative of choice they wish to implement.

Finally, the model is extensible in that practitioners can add their own metrics and benefits/objectives either as replacements or in addition to the ones currently described in the RS-ICMMI implementation instance. In short, RSM model is truly a Rosetta Stone Methodology allowing personnel in the field to freely translate between SPIs, Benefits/Objectives, and Metrics. However, it needed to be validated. This is carried out in two steps – the validation of the Rosetta Stone Methodology (Chapter 5) and the validation of RS-ICMMI (Chapter 6).

5 Rosetta Stone Methodology Validation Process

5.1 Introduction

An expert panel was used to validate both the Rosetta Stone Methodology. This chapter reviews the questions asked of interviewees, reviews and analyses the results of the interviews and to compares the results against what was expected. As described in Chapter 3, the expert panel method was chosen as the appropriate research and analysis tool for this work.

5.2 The Objectives of the Research

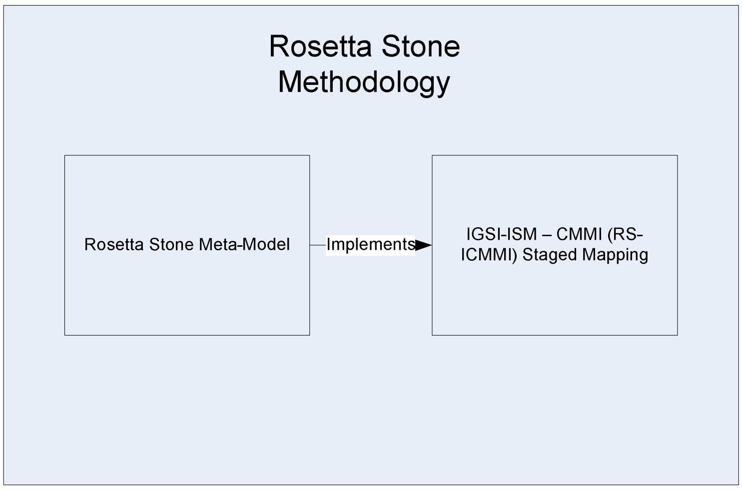

Figure 5-1: Rosetta Stone Meta-Model to Instance Mapping

The work presented in this thesis consists of both the generic Rosetta Stone Methodology and an implementation instance of the Rosetta Stone Methodology - the RS-ICMMI mapping of the IGSI-ISM benefits model to CMMI (Staged) mapping. Logically this mapping is presented in Figure 5-1. While the entire subject area is of interest to the researcher, as a result of this approach to the model, there is a natural break in how to approach the interview – one area is to look at the validity and correctness of the Rosetta Stone Methodology and the associated meta-model model and the other area is to look at the validity and correctness of the mapping instance – the mapping of the IGSI-ISM model to CMMI (Staged). In addition to these two areas, I was interested in some general questions – is this approach new and worthy of research and, if the approach is in fact novel, what are the reasons that practitioners undertake SPI in general and my model in particular? Using MindMapping techniques (Buzan 2006), I developed a MindMap of all the research questions. In addition to the questions, all the other items which would be required in an interview were added as an aide-memoir into the MindMap. The resulting MindMap is shown in Figure 5-2. We shall now discuss each of the individual sections in the MindMap.

5.2.1 Introductory Section

The purpose of the Introductory section is to give the interviewee a sense of who I am and why they are being asked to participate in the research. In addition, it gave me the opportunity to describe the layout of the interview process and how long the interview process would take. At this point in the interview, I also asked permission to record each interview.

5.2.2 Background Information on the Interviewee

The credentials of the interviewee were established during this part of the interview. Where applicable, the academic credentials, as well as the work experience of the interviewee were gathered. As most of the interviewees worked either for for-profit companies or for companies which work on United States Department of Defence (USDOD) contracts, there was an element of confidentiality involved. As a result, all interviewees were asked if they wished to contribute anonymously to the expert interviews. With the exception of one interviewee, all interviewees allowed their details to be published and even that one person who did not wish to publish his details only asked that his company not be named.

5.2.3 Review of the Methodology

The third section in the interview involved a walk-through of the methodology and meta-model. This was undertaken in the format of a presentation which is included in Appendix F and was part of the materials submitted to all interviewees in advance of the interview. While all interviewees were provided with an overview of both the meta-model and the interview (in the form of the MindMap in Figure 5-2) well in advance of the meeting, that approach did not replace the need for a personal, worked-through review of the model. I therefore walked each interviewee through the full methodology and a cut-down version of the CMMI (Staged) mapping. In the walk-through, I concentrated on the mapping from the IGSI-ISM model to CMMI (Staged) Level 2. The reason for this approach was 3 fold – it allowed me to reduce the time for the interview, particularly as most people do not have a tremendous amount of time to spend on it; at the same time it still allowed me to fully describe both the generic benefits model as well as the IGSI-ISM model; and finally, as anyone that has been involved in CMM or CMMI (Staged) at any level will have had to have progressed at least through to Level 2, it provides a common level of knowledge upon which to base the interview and subsequent questions.

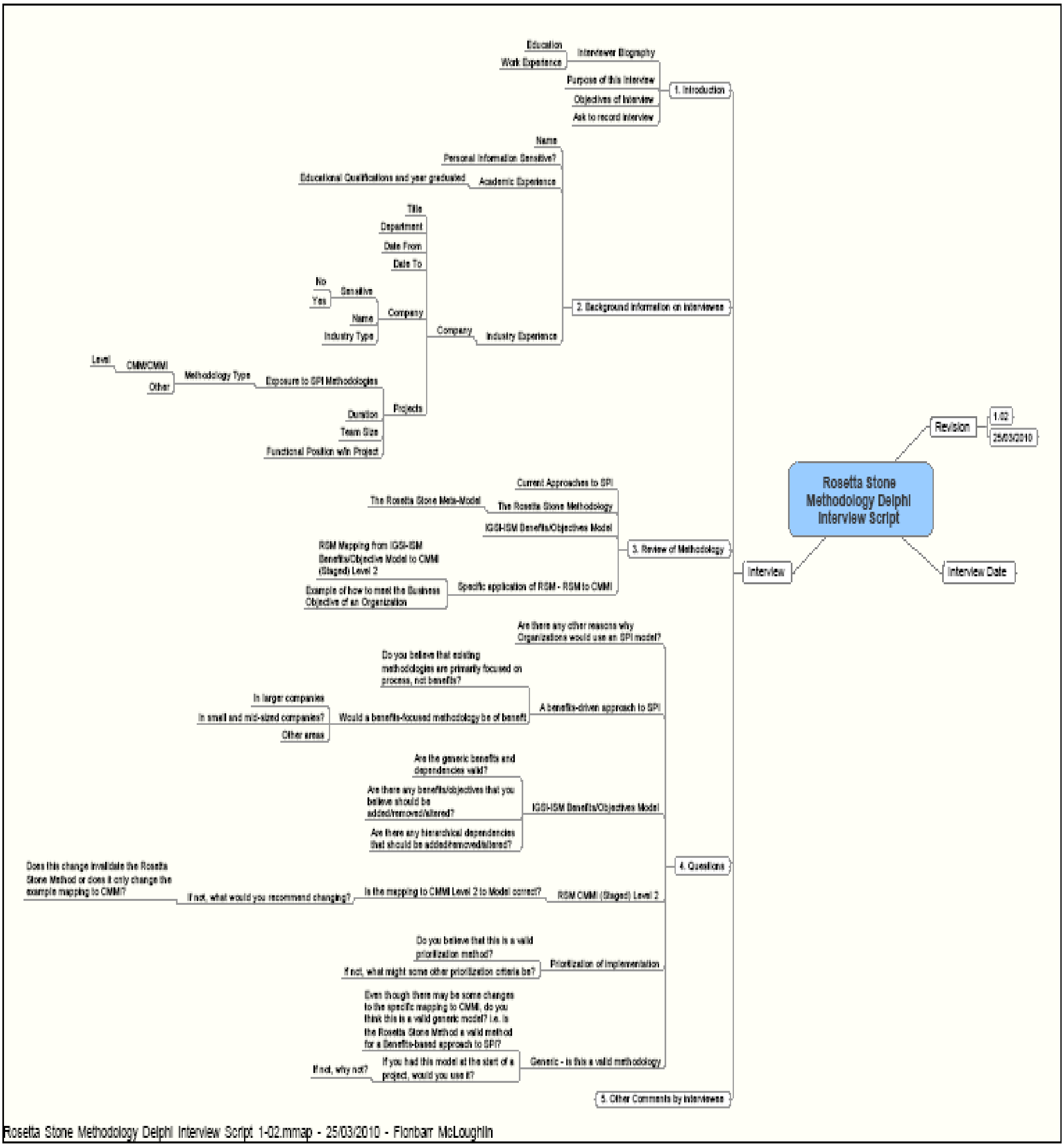

Figure 5-2: Rosetta Stone Expert Panel Interview Mindmap

5.2.4 Questions

As discussed in the chapter on Research Methods, one of the reasons that an expert panel approach was used is that, while directed and scientific in nature, it allows an interviewer to explore answers from interviewees and thus allows them to be less rigid than if they used other forms of response gathering techniques such as questionnaires. As a result, as many of the questions as possible were open-ended in that they allowed interviewees to freely add in their own comments, ideas, and thoughts. This was considered especially important as this is a brand new model which has not been proposed by anyone previously.

The first group of questions posed were about the reasons why organizations would use an SPI model. From discussions with colleagues and through articles in the literature, it appears that organizations might use SPI for a variety of reasons (which we will discuss later in this chapter) but are there any other hidden reasons for undertaking an SPI program? This is relevant to this research as the Rosetta Stone Methodology allows people to focus on business-relevant benefits as the driver for SPI implementation while, traditionally, organizations may have undertaken SPI as a way to obtain USDOD contracts and as market differentiators for consulting companies to differentiate themselves from competitors.

The second group of questions talked to the novelty of the proposed approach – was anyone aware of any other similar, benefits-driven models out there? If so, what were they and was there a direct comparison with the Rosetta Stone Methodology? The reason behind these questions was to demonstrate the uniqueness of the work undertaken in this research and, if it turned out that there was anything similar out there, was it relevant to the methodology? If relevant, was it complementary or did it cast doubt on the approach taken?

The third and fourth groups of questions were about the methodology and meta-model. While the methodology and meta-model are very flexible and appear to make sense at a high level, many of the interviewees found it useful to discuss the methodology in the context of the worked example.

5.2.5 Other Comments by Interviewees

As I wanted to elicit as much information as possible, before closing out each interview, I asked each of them an open-ended question about the model – given the model that they had just reviewed and answered questions about, were there any comments they wished to add?

5.3 Interviewees

For this research, 17 people were interviewed:

Last Name	First Name	Organization
Bhattacharia	Swaraj	International Consulting Company
Chatmon	Al	Northrupp Grumman Electronic Systems Division Inc.
Corkery	Gillian	Fidelity Investments
Dagnino	Aldo	ABB Ltd.
Dittmar	Peter	Northrupp Grumman Electronic Systems Division Inc.
Doyle	Michael	Motorola Ireland
Falvey	Abina	Ericsson Ireland
Fantina	Bob	Research In Motion Inc.
Fried	Steve	Boeing Aerospace
Gatt	Israel	Data Systems Designers
Lucey	Pat	AspiraCon
Millner	Harvey	Satyam
Mitra	Amit	Independent Consultant
O'Kane	Tom	Motorola Ireland and University College Cork
Rayford	Joan	Innovision Technologies
Reeve	April	Citco Technology Management
Reitzig	Rolf	Cognence Inc.

Table 5-1: List of Interviewees

Table 5-2 summarizes their experience.

Statistic	SPI Experience	Total Work Experience
Average	11	19
Median	10	19
Total	188	325
Maximum	22	35
Minimum	4	10

Table 5-2: Summary of interviewee experience

Appendix C contains full details of the interviewees and their experiences. In addition, in order to protect anonymity and to respect the assurances given to the participants in the interview process, random pseudonyms have been given to the interviewees so that, when attributing opinions or quoting interviewees, the pseudonyms are used in the attribution process and not the actual person. These pseudonyms are labelled I1 to I17, where "I" represents Interviewee and the comments and opinions of an interviewee are attributed using a random pseudonym. For example, if I14 (interviewee 14) stated that a mapping was in line with expectations, then the quote could appear as either "I14 stated that the mapping was in line with expectations" or that "the mapping was in line with expectations (I14)."

5.4 Analysis of Interviews

5.4.1 Question Group 1 – Reasons for using SPI

In the literature, several reasons have been identified as to why organizations would engage in a program of SPI. The main reasons put forward in the literature have been that a formal SPI recognition award such as CMMI Level x or ISO-9001 compliance can act as market differentiators for consulting firms who wish to attract clients; in many cases, in particular where organizations wish to compete for government contracts in areas such defence, being in possession of a certain SPI award, such as being CMMI Level 3 compliant, is a necessary prerequisite before even entering into a tender process; and, lastly, many companies undertake SPI programs because they intuitively believe that undertaking such a program will give them benefits in general.

While all the interviewees agreed that the reasons put forward above were very valid and the most likely reasons for undertaking SPI, there were some other reasons put forward by them in the interview process. One local interviewee (I9) stated that SPI can also be an internal differentiator. In particular, in one company that that the person worked in, the fact that the Irish division he worked in was at a particular level of CMM was used by company management as a reason to keep that division open while another division which hadn't been rated in CMM was wound down. I3 echoed this sentiment in that he believed that SPI can aid in the survival of an organization, especially if you are an offshore organization and by undertaking SPI you can show that you can simultaneously execute and show value. By doing this "you are one step ahead of other companies."

All the interviewees agreed that they believe that the 3 reasons described above are widely held by organizations. In particular, I5, I6, and I7 also stated that, even in the absence of formal proof of productivity gains within their organizations, they believe that SPI provides productivity gains. I16, who works for a very large software consulting firm, stated that, while initially he believed that the firm started using SPI for marketing reasons, the firm "now follows it because it has given them a huge discipline and they find it really works." The interviewees unanimously agreed that they believed the existing SPI methodologies were process and IT-focused, not benefits-driven.

While every one of the participants had quite a deal of experience in SPI, there were some SPI general comments which indicated that some of the interviewees have experienced negative feedback on SPI. In particular, I14 stated that one of the problems with CMM/CMMI is that "it is onerous to execute", I12 was of the opinion that "one of the problems with CMMI is that it's a very technical model", and I3 stated that there is "apparently an opinion in the industry that CMMI level 3 is enough [to achieve]" and that "levels 4 and 5 have too much overhead" associated with them. Other apparently negative comments on SPI came from I5 and I6 who stated that "large companies also have an issue of pointing out what the benefits of SPI are." This feeling was also echoed by I9 when he said that it is "not clear what the main benefits of SPI are." I5 and I6 were also somewhat critical of SPI as they felt that "project managers sometimes see SPI as overhead" rather than a tool that can add value to their projects. We should note here that the while many of the negative comments are obviously aimed at CMM/CMMI, we should also recognize that the vast majority of all interviewees' experiences centre around CMM/CMMI. Criticism of CMM/CMMI is not new and, as we have seen in section 2.10, tends not to relate to individual SPI processes but rather the overhead associated with CMM/CMMI as a whole.

5.4.2 Question Group 2 – Novelty of Approach

With regard to the novelty of the work, the interviewees unanimously agreed that they knew of no other benefits-driven methodology and that all the methodologies that they were aware of are process- and not benefits-driven. While all the interviewees saw the value of a benefits-driven approach, several interviewees made some particular comments as to why it was a good approach. I9 pointed out that, while people in general feel that SPI is good, a lot of practitioners are not particularly aware of the specific value of undertaking SPI and this approach goes a long way to addressing the value of undertaking SPI. I12 stated that there was a perception that CMMI came with a high overhead associated with it and a benefits approach made it easy to see the business benefits from SPI. In a similar vein, I5 stated that there was a common conception, particularly within the project management community, that SPI is an overhead that gets in the way of doing real work but the Rosetta Stone approach can be used to demonstrate to "people in the trenches" why to use SPI. In addition, I6 thought that it was a very useful translation tool "to connect business benefits to a proven pedigree [SPI methodology]". I4 thought that a benefits-driven approach is especially useful as some "companies want to improve at their own pace using established standards in a systematic fashion" and that the Rosetta Stone approach is a "structured systematic way to prioritize SPI". Another advantage of this approach is that an "organization is not required to make a massive investment straight away – a distinct advantage" (I10) and it "makes the approach very tangible" to people on the ground. This last comment is also reflected by comments from I5 and I6 – the "tool can be used to demonstrate to 'people in the trenches' why to use SPI." I12 is of the opinion that "it's definitely a good approach – not quantitative but I doubt if it's realistically possible to have a quantitative approach as most companies don't have that information - no-one has that information."

The other question posed in this group of questions was on the applicability of this methodology to large, medium, and small companies. My initial thoughts were that this methodology would be of more use to small companies who have definite business needs and who don't have either a need to be at a certain level of SPI compliance or who don't have the money to do so. In this area I was surprised in that, while everyone agreed it would be useful to all types of company, several people were of the opinion that it would be of particular use to large companies. In particular, one person who has worked as a consultant in many different companies (I12) stated that CMMI is a very technical model and that senior business management are not at all interested in SPI. Therefore any methodology which allows business management to see the concrete benefits of spending money on SPI would be particularly useful in large companies where IT is a distinct organization separated out from the business. I17 was also of the opinion that the Rosetta Stone Methodology was of particular relevance to large companies as they spend a lot of money on CMMI. In his opinion, using the RS-ICMMI mapping instance, you can target specific business objectives without having to implement an entire CMMI level, thus saving the organization money. He also expressed the opinion that the methodology could have a very good impact of the bottom line of small companies from a benefits perspective. One interesting point noted by I15 was that the interviewee believed that the benefit to smaller companies would depend on the culture of the company – many smaller companies do not have a process-driven driven culture so an approach like this could possibly be difficult from a cultural rather than an implementation perspective. Again, from an SME perspective, I3 stated that SPIs such as CMMI are perceived to have a high overhead associated with them and that an approach like the Rosetta Stone shows benefits and would therefore have a higher chance of uptake.

5.4.3 Question Group 3 – The IGSI-ISM – CMMI (Staged) Level 2 Mapping

While research into a theoretical methodology such as the generic Rosetta Stone Methodology is appropriate from a generic perspective, it was the research on the specific mapping from the IGSI-ISM model to CMMI (Staged) that generated most discussion from the interviewees. As can be seen in Figure 5-2, the questions in Group 4 were focused on 3 specific areas – the IGSI-ISM benefits model, the mapping from the model to CMMI (Staged) Level 2, and the prioritization of the mapping implementation.

While researching the methodology, interviewees were told that the benefits model presented in the mapping instantiation (the IGSI-ISM model) was only one of a number of possible benefits models. However, as all the interviewees were either employed at one stage at commercial organizations or currently work for commercial organizations, much interest was generated on the IGSI-ISM benefits model. The interviewees universally agreed that the IGSI-ISM model is a very good broad, commercial benefits model. Just over half (9 out of 17) would have accepted the model presented while the remainder thought there might be some minor changes which could be made but they were satisfied that the model met at least 80% of their expectations, given their prior industrial experience. The remainder of the interviewees agreed that any changes they could suggest were organization-specific and would not affect the overall validity of the IGSI-ISM model. In line with the fact that it is a generic model and different benefits models could be used in a mapping instantiation, I5 and I6 suggested that there could be different models for Quality, Cost, and Schedule within an organization. This approach is in line with the PMI's impact triangle (PMI 2004) – any change to one of those objectives will impact the other two.

With regard to the proposed changes to the IGSI-ISM model, I2 commented that he personally believed that there should be a stronger link between Better Quality Product and Higher Quality Management as well as between Efficient Resource Management and Increased Productivity. In addition "Efficient Resource Management impacts more than just Better Risk Management" and that there should be direct links between Predictability and Increased Productivity. Both I3 and I17 also suggest that there should be a direct link between Efficient Resource

Management and Increased Productivity. This is also echoed by I1 who comments that "Predictability should be directly affected by Efficient Resource Management as you can't predict what you can do because you don't know what people you have doing it." I17 also states that he believes that there should be a link between Better Product Quality and Setting Customer Expectations. Figure 7-1 shows a modified version of the IGSI-ISM model with the suggested changes incorporated into the model. It should be noted, however, that such changes to the model change only the secondary benefits derived from implementation of certain PAs and do not change in any way the primary benefits of implementation of particular PAs.

The next question concerned the mapping from the benefits model to CMMI (Staged) Level 2. Implicit in this is the concept of primary and secondary benefits. Again, interviewees unanimously agreed that the mapping from the IGSI-ISM model was in general an understandable and valid mapping. The only questions that were raised were around the benefits model, not around the mapping from the benefits model to CMMI. I12 stated that it is definitely a good approach but is not a quantitative approach. I3 stated that it was a logical way to arrive at the mapping. I7 in particular liked the concept of primary and derived benefits as it allows you to focus on particular benefits while it also lets you see what benefits you get "for free."

From a prioritization perspective, everyone agreed that the prioritization approach was very understandable and that it was appropriate to use the CMMI Staged Levels as a natural prioritization mechanism. I4, while agreeing that the initial prioritization rules are valid and well-founded, suggested that in the longer term, as a refinement to the model, a weighting scheme might be put into place that would allow certain process areas to be weighted above others. I13 agreed with the prioritization scheme "up to a point" and suggested that it might be possible to mix Levels 2 and 3 together while continuing to have a separation between Levels 4 and 5.

5.4.4 Question Group 4 – The Rosetta Stone Methodology and Meta-Model

Everyone agreed that the generic model is valid and makes sense. I17 commented that it "is a genuine attempt to associate business drivers with process improvement". I16 stated that the approach is very tangible. I10 "liked it very much – a definite strength". I1 noted that it was "easy to see what you need to do to get results". I14 noted that "what I like about the model is that going into it, if you know exactly what you want out of it, it's easy to see what you have to put in place to get it" as well as "Yes I do [like it] especially in the scenario of …. 'If you do these things then…'" I12 stated that it was "Very clear – I'm familiar with a few generic models and in this one you don't need a PhD to use it" and that "I like it a lot; I like a step by step approach and that someone can pick it up and achieve specific goals", and "it can help them [SPI experts] move out of the abstract and into their [the company's] business. Business leaders who control things don't care about specific or generic practices - the care about what it means to their business." I3 stated that "I have done it [for customers] based on experience. I don't have a model-based approach. This is actually very interesting." I8 stated that it "seems a practical, tangible approach that you can identify with."

In order to determine how useful the methodology is, and in order to see if the interviewees thought the methodology was useful, I asked the interviewees if they would consider using the RS-ICCMMI mapping instance in their work. The interviewees unanimously agreed that they would consider using the instance if an appropriate application for it came up. In fact, 6 of the interviewees asked for specific permission to use the instance and/or share it with co-workers for their comments on it.

5.4.5 Other comments and Future Enhancements

From analysis of the interviews, respondents concluded that the methodology and the RS-IMMI mapping instance look reasonable and appear to be well-founded but asked were there any plans to test it out in practice. I13 and I12 would both like some empirical evidence to back the model up but, equally, they recognize that finding such evidence may be difficult, if not impossible. As a result, they suggested that an empirical review might be worthwhile as a next step in the evolution of the RS-ICMMI mapping instance. I15 noted that:

> "I like the Chart on page 10 (IGSI-ISM Model) and page 20 (order PA recommendations, including primary vs. secondary ordering).It just needs to be marketed a bit better. Right now, it looks very 'engineeringy'. Senior management needs to have presented differently from 'engineeringy'."

The implication is that while the model is sound, it may benefit from a more business-friendly representation.

From a usefulness perspective, I15 noted that the interviewee is frequently asked what particular PA gives you the biggest bang for the buck and that this methodology and mapping instance provides answers. I14 was of the opinion that organizations need a way to determine the most critical things to do and that will depend on the business situation. This methodology and mapping instance are something that could let people and organizations move in that direction and is therefore useful. I5 and I6 believe that many IT people and PMs in particular shy away from assigning financial value to IT initiatives. Therefore they would like to see some concrete examples of ROI and have those worked out as templates for IT project managers.

5.4.6 Summary

In summary, 17 people with an average of 19 years industry experience and 11 years SPI experience participated in the expert panel. The interview responses were analyzed and results demonstrate that there doesn't appear to be any similar model or methodology available which allows organizations to drive from a business benefits perspective back to SPI. In addition, they all agreed that the methodology is valid, logical, and, from their experiences, makes sense.

On the specific mapping instantiation of the IGSI-ISM model to CMMI (Staged) Level 2, results showed that the mapping and prioritization of the benefits to CMMI Level 2 were understandable, logical, and scientific in their approach. The only area where everyone was not agreed was on the completeness of the IGSI-ISM model, which in any case is an external model outside of the scope of this research. Everyone was agreed, however, that the IGSI-ISM model was a good basis on which to start and which, with some minor changes, could be modified to suit individual organizations. In fact, 9 out of 17 of the interviewees would use the current version of the IGSI-ISM model as it stands.

While everyone agreed that they would use this model if they had a need, 6 interviewees, without prompting, asked for more details on the entire CMMI (Staged) mapping and not just the Level 2 mapping which was used in the interview. They also asked for permission to use this approach in their work.

The research for this work was achieved using a variety of means – my own personal experience, input from colleagues, literature review of general engineering best practices such as code inspections, and literature review of particular SPI methodologies such as CMM/CMMI, ISO-9001, and ISO/IEC 15504. Of particular concern to me was the possibility, however remote, that I had left out any other way of researching the benefits of SPI. As a result, and as a means of demonstrating how the research was arrived at, I detailed to the interviewee how I had arrived at the methodology and the mapping instance. As a way of validating this approach, one of the questions I asked was if there was any other way to arrive at this research? I acknowledged that I had tried unsuccessfully to work with companies to perform a study and also, due to the fact that this is a novel approach, it was not possible to find empirical evidence to directly support the model. With the exception of an empirical study (as suggested by I7, I12, and I13), no-one came up with any suggestions other than those methods I discuss in this study. However, these particular interviewees also recognize that getting empirical data on this is virtually impossible with I12 stating that "no-one has that information."

Interviewees offered no further suggestions as to how to get the raw information for the research. As a result, all the interviewees agreed that it was unlikely that the research could be carried out in a different manner.

6 RS-ICMMI Validation Process

6.1 Introduction

Having reviewed the Rosetta Stone Methodology at a high level and subjected both the meta model and the methodology to a validation process, the next phase in the research process was to review and validate the RS-ICMMI model. The objective of this phase of the research process, therefore, was to rigorously evaluate the relationships between the IGSI-ISM Benefits Model and the CMMI Process Areas as defined in the RS-ICMMI mapping between CMMI and the IGSI-ISM Benefits model. This was carried out by interviewing experts on the explicit relationships in the model. In this chapter, I present all the relationships discussed and the reasoning used by the experts during the interviews. In section 6.3 I present an updated model based on the interview results.

6.2 Validation of Process Area/Benefits Mapping

For validation, each PA/Benefit combination has been reviewed by 2 separate interviewees (as described in section 3.9). For primary benefits, the expected benefits have been accepted by the interviewees and only one new potential primary benefit has been promoted from the remaining PA/Benefit combinations. The secondary PA/Benefit combinations also went through a validation process, though the results indicate the secondary PA/Benefits combinations are not as compliant with expectations as the primary PA/Benefits mappings. The original mapping has been altered to take the results of the validation process into account and the updated mapping is presented in Section 6.3.

6.2.1 Requirements Management

When presented with the REQM relationship, the first interviewee had direct experience of including customers into REQM which had a direct effect on *Understanding Customer Needs* and also noted that, in his experience, if a customer knows what he wants, then it cuts down on re-work (and thus creating a Lower Time to Market). However, as he has experienced, not many customers know exactly what they want. Based on his experience, he proposed that REQM might possibly have a primary impact on *Setting Right Customer Expectations* while REQM will definitely lead to a *Better Quality Product* as a primary benefit. In addition, the second interviewee thought that *Higher Customer Satisfaction* would be a primary benefit of REQM as he believes in the ability to talk to your clients. Both interviewees thought that an increase in *Predictability* may possibly be a primary benefit of REQM and not merely a secondary benefit. As can be seen in Table 6-1, there is 100% compliance between interviewees' experiences and the expected primary benefits for Requirements Management (REQM).

Process Area	**IGSI-ISM Benefit**	**RS-ICMMI Model**	**Interviewee 1 Results**	**Interviewee 2 Results**	**Compliance to RS-ICMMI**
Requirements Management	Better Risk Management (4-2)	Y	Y	Y	100%
Requirements Management	Understanding Customer Needs (4-4)	Y	Y	Y	100%
Requirements Management	Lower Time to Market (5-2)	Y	Y	Y	100%

Table 6-1: Expected primary benefits of REQM

For secondary benefits, on a summary level, of 19 remaining PA/Benefit combinations:

- 9 combinations are 100% compliant with expectations
- 6 combinations are 50% compliant
- 4 combinations are 0% compliant.

Both interviewees agreed that REQM definitely has a secondary impact on *Increased Productivity*. Again, both agreed that REQM has a secondary impact on creating a *Better Quality Product* with one of them going so far as to say that he would even consider it a primary benefit while both again agreed that REQM has a secondary impact on *Skill Development Facilitation By Management*.

While both interviewees have given their answers based on their experience in practice, one interviewee who used to work for a large, multi-national company provided specific evidence to support the impact on REQM on *Retain and Develop Skills and Domain Knowledge*. At that company, apparently the company performed a full review of all requirements across products and used this to specialize knowledge of specific parts of the requirements across specific geographic areas, thus allowing them to locate specific skills in particular geographies. He found this to provide a great advantage to them in developing products.

Process Area	IGSI-ISM Benefit	RS-ICMMI Model	Interviewee 1 Results	Interviewee 2 Results	Compliance to RS-ICMMI
Requirements Management	Increased Revenues/Profits	Y	Y	Y	100%
Requirements Management	Image	Y	Y	Y	100%
Requirements Management	Higher Customer Satisfaction	Y	Y	Y	100%
Requirements Management	Market Reach	N	N	N	100%
Requirements Management	Increased Productivity	N	Y	Y	0%
Requirements Management	Setting right Customer Expectations	N	Y	N	50%
Requirements Management	Predictability	Y	Y	Y	100%
Requirements Management	Competitive Proposals	Y	N	Y	50%
Requirements Management	Better Quality Product	N	Y	Y	0%
Requirements Management	Efficient Resource Management	Y	Y	Y	100%
Requirements Management	Retain & Develop Skills & Domain Knowledge	Y	Y	Y	100%
Requirements Management	Skill Development Facilitation by Management	N	Y	Y	0%
Requirements Management	Efficient Information Management	N	Y	N	50%
Requirements Management	Teaming / Synergize	N	Y	N	50%
Requirements Management	New Technology	N	N	Y	50%
Requirements Management	Improved Institutionalization of tools / process / methods	N	N	N	100%
Requirements Management	Business Focus	N	N	N	100%
Requirements Management	Market Intelligence	Y	N	N	0%

Table 6-2: Other Process Area/Benefit combinations for REQM

6.2.2 Project Planning

Process Area	IGSI-ISM Benefit	RS-ICMMI Model	Interviewee 1 Results	Interviewee 2 Results	Compliance to RS-ICMMI
Project Planning	Better Quality Product (4-1)	Y	Y	Y	100%
Project Planning	Better Risk Management (4-2)	Y	Y	N	50%
Project Planning	Predictability (3-4)	Y	Y	Y	100%
Project Planning	Setting Right Customer Expectations (3-3)	Y	N	Y	50%
Project Planning	Competitive Proposals (3-5)	Y	Y	Y	100%
Project Planning	Efficient Resource Management (4-3)	Y	Y	Y	100%
Project Planning	Understanding Customer Needs (4-4)	Y	N	Y	50%

Table 6-3: Primary benefits of PP

With regard to the impact of PP on *Better Risk Management*, one interviewee was in agreement with the expected impact while the other was on the borderline and suggested that it might be a strong secondary impact rather than a primary one. According to the interviewee he would have been happy accepting either but, as he was not 100% confident that *Better Risk Management* is a primary impact of PP, his response was interpreted as not being conformant with expectations. With regard to the impact of PP on *Setting Right Customer Expectations,* the first interviewee stated that, while he has seen this impact in practice, he felt that it was more a secondary than a primary impact. The impact of PP on *Understanding Customer Needs*, according to the first interviewee, is not necessarily a primary impact, though he says that he could see why some people might see it as a primary impact. His logic behind his response was that planning will not help unless requirements are correct in the first place. As a result, he feels that PP is of secondary importance to REQM.

One interviewee suggested that the impact of PP on *Skill Development Facilitation By Management* could possibly be a primary impact and not just a secondary impact. His logic for this is that skill analysis and facilitation is often a neglected aspect of PP as many skills are qualitative in nature and not quantitative. As a result, many project managers tend to stay away from this aspect of PP in practice but, in theory, they should not do so.

Process Area	IGSI-ISM Benefit	RS-ICMMI Model	Interviewee 1 Results	Interviewee 2 Results	Compliance to RS-ICMMI
Project Planning	Increased Revenues/Profits	Y	Y	Y	100%
Project Planning	Image	Y	Y	Y	100%
Project Planning	Higher Customer Satisfaction	Y	Y	Y	100%
Project Planning	Market Reach	Y	Y	Y	100%
Project Planning	Increased Productivity	Y	Y	Y	100%
Project Planning	Retain & Develop Skills & Domain Knowledge	N	Y	N	50%
Project Planning	Lower Time to Market	N	Y	N	50%
Project Planning	Skill Development Facilitation by Management	N	N	Y	50%
Project Planning	Efficient Information Management	N	N	Y	50%
Project Planning	Teaming / Synergize	N	Y	N	50%
Project Planning	New Technology	N	N	N	100%
Project Planning	Improved Institutionalization of tools / process / methods	N	N	N	100%
Project Planning	Business Focus	N	N	N	100%
Project Planning	Market Intelligence	N	N	N	100%

Table 6-4: Other Process Area/Benefit combinations of PP

In summary, of the 15 remaining PA/Benefit combinations for PP, 9 combinations for 100% compliant, while 6 are 50% compliant. As mentioned in the previous section, one interviewee noted that the impact of PP on *Skill Development Facilitation* should perhaps be a primary impact. Of the remaining non-compliant answers, one interviewee has seen in practice where PP can have an impact on *Retain and Developing Skill* but not on domain knowledge. As a result, he argued that there is at least a partial impact of PP on *Retain and Develop Skill and*

Domain Knowledge. The same interviewee also argued that PP has an impact on *Lower Time to Market* as it helps in terms of good estimation and scheduling, therefore allowing projects to deliver on time – and not deliver on time otherwise. Another interviewee, who has a background in both small and large organizations, argues that PP has an impact on *Efficient Information Management* in small organizations as, in small organizations, everyone knows everything and thus PP can allow *Efficient Information Management*. He does, however, acknowledge this is not the case for large organizations and states that as organizations grow larger the impact of PP becomes less important.

6.2.3 Project Monitoring and Control

Process Area	**IGSI-ISM Benefit**	**RS-ICMMI Model**	**Interviewee 1 Results**	**Interviewee 2 Results**	**Compliance to RS-ICMMI**
Project Monitoring and Control	Better Quality Product (4-1)	Y	Y	Y	100%
Project Monitoring and Control	Better Risk Management (4-2)	Y	Y	Y	100%
Project Monitoring and Control	Efficient Resource Management (4-3)	Y	Y	Y	100%
Project Monitoring and Control	Setting Right Customer Expectations (3-3)	Y	Y	Y	100%

Table 6-5: Primary benefits of PMC

Both interviewees are 100% compliant with expectations for PMC. The first interviewee noted that, in his experience, there is definitely a primary impact of PMC on a *Better Quality Product* because if you don't perform any necessary remediation early, this will impact quality. In addition, he also notes that "half of good risk management is within PMC." From the second interviewee's perspective, the impact of PMC on *Setting Right Customer Expectations* depends on individual organizations as, in many cases, the customer can't often directly see any impact of PMC on their product.

In summary, of the 17 Process Area/Benefit combinations for PMC:

- 12 combinations are 100% compliant
- 4 combinations are 50% compliant
- 1 combination is 0% compliant.

With regard to the impact of PMC on *Retain and Develop Skills and Domain Knowledge*, the first interviewee acknowledges that, in theory, the implementation of PMC should lead to *Retain and Develop Skills and Domain Knowledge*. However, in practice, he says that he has not seen such an impact. The second interviewee acknowledges PMC impacts both *Lower Time to Market* and *Efficient Information Management* in a weak manner. As discussed earlier, in the event that an interviewee is not 100% sure of an answer, the answer is deemed not to be true. In this case, therefore, as the interviewee was not 100% confident that there is a strong cause and effect relationship between PMC and the 2 benefits in question, it is assumed that there is no relationship and the impact is modelled accordingly.

Process Area	**IGSI-ISM Benefit**	**RS-ICMMI Model**	**Interviewee 1 Results**	**Interviewee 2 Results**	**Compliance to RS-ICMMI**
Project Monitoring and Control	Increased Revenues/Profits	Y	Y	Y	100%
Project Monitoring and Control	Image	Y	Y	Y	100%
Project Monitoring and Control	Higher Customer Satisfaction	Y	Y	Y	100%
Project Monitoring and Control	Market Reach	Y	Y	Y	100%
Project Monitoring and Control	Increased Productivity	Y	Y	Y	100%
Project Monitoring and Control	Competitive Proposals	N	Y	Y	0%
Project Monitoring and Control	Understanding Customer Needs	N	N	N	100%
Project Monitoring and Control	Retain & Develop Skills & Domain Knowledge	N	Y	N	50%
Project Monitoring and Control	Lower Time to Market	N	Y	N	50%
Project Monitoring and Control	Skill Development Facilitation by Management	N	N	N	100%
Project Monitoring and Control	Efficient Information Management	N	Y	N	50%
Project Monitoring and Control	Teaming / Synergize	N	N	N	100%
Project Monitoring and Control	New Technology	N	N	N	100%
Project Monitoring and Control	Improved Institutionalization of tools / process / methods	N	N	N	100%
Project Monitoring and Control	Business Focus	N	N	N	100%
Project Monitoring and Control	Market Intelligence	N	N	N	100%

Table 6-6: Other Process Area/Benefit combinations of PMC

The RS-ICMMI instance expects PMC to not have any impact on *Competitive Proposals*. However, both interviewees differ from the instance expectation. The first interviewee notes that he has actually seen a cause and effect relationship in practice.

6.2.4 Supplier Agreement Management

Process Area	IGSI-ISM Benefit	RS-ICMMI Model	Interviewee 1 Results	Interviewee 2 Results	Compliance to RS-ICMMI
Supplier Agreement Management	Lower Time To Market (5-2)	Y	Y	Y	100%
Supplier Agreement Management	Better Quality Product (4-1)	Y	Y	Y	100%
Supplier Agreement Management	Better Risk Management (4-2)	Y	Y	Y	100%
Supplier Agreement Management	Predictability (3-4)	Y	Y	Y	100%

Table 6-7: Primary benefits of SAM

All the interviewees' answers are in 100% compliance with the expected impacts of Supplier Agreement Management (SAM). In particular the first interviewee, who worked in a large organization where there were supplier agreements across individual units within the organization, noted that if SAM is put in place there are very few variances from the agreement and this will thus have a very positive effect on many different things. The second interviewee also notes that SAM can help drive things to market and, when it is used, it definitely has a positive impact on many things.

In summary, of the 18 Process Area/Benefit combinations for PMC:

- 13 combinations are 100% compliant
- 3 combinations are 50% compliant
- 2 combinations are 0% compliant.

There were 3 Process Area/Benefit combinations which were 50% compliant with interviewees' experiences. The second interviewee found that there is in fact a cause and effect relationship between SAM and *Competitive Proposals*. His experience was that, if you do not have SAM in place, it may be an indication that your processes in general are quite loose. This can then have an impact on your ability to produce *Competitive Proposals*. The same interviewee noted that if the supplier(s) who is/are subject to the SAM provide new technology in particular, then SAM can definitely have an impact on *New Technology*. However, at the same time, he notes that if the Supplier/SAM does not have anything to do with new technology, then there may not be any impact. The first interviewee merely noted that, in his experience, SAM did not have any effect on *Teaming/Synergize*.

Process Area	IGSI-ISM Benefit	RS-ICMMI Model	Interviewee 1 Results	Interviewee 2 Results	Compliance to RS-ICMMI
Supplier Agreement Management	Increased Revenues/Profits	Y	Y	Y	100%
Supplier Agreement Management	Image	Y	Y	Y	100%
Supplier Agreement Management	Higher Customer Satisfaction	Y	Y	Y	100%
Supplier Agreement Management	Market Reach	Y	Y	Y	100%
Supplier Agreement Management	Increased Productivity	Y	Y	Y	100%
Supplier Agreement Management	Setting right Customer Expectations	Y	Y	Y	100%
Supplier Agreement Management	Competitive Proposals	N	N	Y	50%
Supplier Agreement Management	Efficient Resource Management	N	Y	Y	0%
Supplier Agreement Management	Understanding Customer Needs	N	N	N	100%
Supplier Agreement Management	Retain & Develop Skills & Domain Knowledge	N	N	N	100%
Supplier Agreement Management	Skill Development Facilitation by Management	N	N	N	100%
Supplier Agreement Management	Efficient Information Management	N	Y	Y	0%
Supplier Agreement Management	Teaming / Synergize	N	Y	N	50%
Supplier Agreement Management	New Technology	N	N	Y	50%
Supplier Agreement Management	Improved Institutionalization of tools / process / methods	N	N	N	100%
Supplier Agreement Management	Business Focus	N	N	N	100%
Supplier Agreement Management	Market Intelligence	N	N	N	100%

Table 6-8: Other Process Area/Benefit combinations of SAM

There were 2 Process Area/Benefit combinations which were not in compliance with interviewees' experiences. Both interviewees were of the opinion that SAM has an effect on *Efficient Resource Management*. This was based on the fact that an organization would not enter into a SAM unless there was some resource benefit to it – it allowed them to free up their internal resources. In addition, they were of the opinion that SAM allowed Efficient *Information Management* based on the fact that there would have been some agreed-upon Service Level Agreements (SLAs) in the contract, which are in and of themselves information.

6.2.5 Measurement and Analysis

Process Area	**IGSI-ISM Benefit**	**RS-ICMMI Model**	**Interviewee 1 Results**	**Interviewee 2 Results**	**Compliance to RS-ICMMI**
Measurement and Analysis	Lower Time To Market (5-2)	Y	Y	Y	100%
Measurement and Analysis	Better Quality Product (4-1)	Y	Y	Y	100%
Measurement and Analysis	Better Risk Management (4-2)	Y	Y	Y	100%
Measurement and Analysis	Predictability (3-4)	Y	Y	Y	100%

Table 6-9: Primary benefits of MA

All the responses for Measurement and Analysis (MA) are 100% compliant with interviewees' experiences. With regard to the impact of MA on *Better Quality Product*, both interviewees had evidence to support their answers. The first interviewee stated that, in his experience, projects that are not measured tend to bow to pressures about release dates while the second interviewee has specific experience that shows when people are aware they're being tracked, they change their mindsets and consequently improve the quality of the product being produced. According to the second interviewee, MA impacts *Predictability* directly. According to him, he has seen that if you don't have historical data then "project planning is more of an art than a science."

In summary, of the 18 Process Area/Benefit combinations for MA:

- 10 combinations are 100% compliant
- 6 combinations are 50% compliant
- 2 combinations are 0% compliant.

There were 6 Process Area/Benefit combinations which were 50% compliant with interviewees' experiences. In stating that there is a positive cause and effect relationship between MA and *Competitive Proposals*, the second interviewee states that it makes sense because if you measure accurately, you put just the right amount of resources in place and therefore cut down on waste. This then leads to competitive proposals. Again according to the second interviewee, there is a positive correlation between MA and *Skill Development Facilitation by Management*. The reason that the interviewee gives for this is that if accurate measurements are taken of the development process and specific components are buggy, the developers writing the buggy code may be identified and targeted training can then be given to the developers in question. The same interviewee also states that there is a positive correlation between MA and *Teaming/Synergize* as he saw this effect in a consulting firm he worked for when low-level measurements were being taken on a daily basis. The second interviewee thought that there was a logical positive relationship between MA and New Technology.

There were 2 combinations which were 0% compliant with expectations. For the relationship between MA and *Market Reach*, the second interviewee did not feel competent to answer this question and, in order to be consistent with how weak or inconclusive answers are dealt with, it was deemed that the answer would be deemed to be a "no." For the relationship between MA and *Improved Institutionalization of Tools/Process/Methods*, both interviewees disagreed with expectations. The second interviewee's analysis was that if things are being measured and analysed, issues (if there are any) will be seen. This may in turn lead to institutionalization of new technology or methods in order to solve the issues.

Process Area	IGSI-ISM Benefit	RS-ICMMI Model	Interviewee 1 Results	Interviewee 2 Results	Compliance to RS-ICMMI
Measurement and Analysis	Increased Revenues/Profits	Y	Y	Y	100%
Measurement and Analysis	Image	Y	Y	Y	100%
Measurement and Analysis	Higher Customer Satisfaction	Y	Y	Y	100%
Measurement and Analysis	Market Reach	Y	N		0%
Measurement and Analysis	Increased Productivity	Y	N	Y	50%
Measurement and Analysis	Setting right Customer Expectations	Y	Y	Y	100%
Measurement and Analysis	Competitive Proposals	N	N	Y	50%
Measurement and Analysis	Efficient Resource Management	N	N	Y	50%
Measurement and Analysis	Understanding Customer Needs	N	N	N	100%
Measurement and Analysis	Retain & Develop Skills & Domain Knowledge	N	N	N	100%
Measurement and Analysis	Skill Development Facilitation by Management	N	N	Y	50%
Measurement and Analysis	Efficient Information Management	N	N	N	100%
Measurement and Analysis	Teaming / Synergize	N	N	Y	50%
Measurement and Analysis	New Technology	N	N	Y	50%
Measurement and Analysis	Improved Institutionalization of tools / process / methods	N	Y	Y	0%
Measurement and Analysis	Business Focus	N	N	N	100%
Measurement and Analysis	Market Intelligence	N	N	N	100%

Table 6-10: Other Process Area/Benefit combinations of MA

6.2.6 Process and Product Quality Assurance

Process Area	IGSI-ISM Benefit	RS-ICMMI Model	Interviewee 1 Results	Interviewee 2 Results	Compliance to RS-ICMMI
Process and Product Quality Assurance	Improved Institutionalization of tools/process/methods (7-1)	Y	Y	Y	100%
Process and Product Quality Assurance	Lower Time To Market (5-2)	Y	Y	Y	100%
Process and Product Quality Assurance	Better Quality Product (4-1)	Y	Y	Y	100%
Process and Product Quality Assurance	Better Risk Management (4-2)	Y	Y	Y	100%
Process and Product Quality Assurance	Predictability (3-4)	Y	Y	Y	100%

Table 6-11: Primary benefits of PPQA

All the responses for Process and Product Quality Assurance (PPQA) are 100% compliant with interviewees' experiences. In particular, the first interviewee believes there is a positive relationship between PPQA and *Improved Institutionalization of Tools/Process/Methods* because "if [PPQA] tools are useful, then they [software professionals] will use them. The second time around, if they find them useful, they will then ask for more [tools]." The same interviewee is also of the opinion that there is a positive relationship between PPQA and *Lower Time to Market* as "most project delays arise from problems at the backend of the project. Anything which can shake things around at the front-end of the project can certainly save time." With regard to the relationship between PPQA and *Better Risk Management*, "evidence of risk management tends to be qualitative and therefore hard to judge objectively" and has seen specific evidence that there is a positive relationship between PPQA and *Better Risk Management*. The second interviewee notes that there is a positive relationship between PPQA and *Lower Time to Market* but believes that the industry that an organization resides in has some bearing on this relationship. If an organization is to be compared across its peers within a particular industry (who are all subject to the same level of regulation), then the second interviewee believes that there is a positive relationship between PPQA and *Lower Time to Market*. However, this is not the case if you're comparing between two organizations that are subject to different regulations – the organization with the smaller amount of regulation would have a lower time to market than the organization with the higher amount of regulation.

Process Area	IGSI-ISM Benefit	RS-ICMMI Model	Interviewee 1 Results	Interviewee 2 Results	Compliance to RS-ICMMI
Process and Product Quality Assurance	Increased Revenues/Profits	Y	Y	Y	100%
Process and Product Quality Assurance	Image	Y	Y	Y	100%
Process and Product Quality Assurance	Higher Customer Satisfaction	Y	Y	Y	100%
Process and Product Quality Assurance	Market Reach	Y	Y	Y	100%
Process and Product Quality Assurance	Increased Productivity	Y	Y	Y	100%
Process and Product Quality Assurance	Setting right Customer Expectations	Y	Y	Y	100%
Process and Product Quality Assurance	Competitive Proposals	N	N	Y	50%
Process and Product Quality Assurance	Efficient Resource Management	N	Y	N	50%
Process and Product Quality Assurance	Understanding Customer Needs	N	N	Y	50%
Process and Product Quality Assurance	Retain & Develop Skills & Domain Knowledge	N	N	Y	50%
Process and Product Quality Assurance	Skill Development Facilitation by Management	N	Y	Y	0%
Process and Product Quality Assurance	Efficient Information Management	N	Y	Y	0%
Process and Product Quality Assurance	Teaming / Synergize	N	Y	Y	0%
Process and Product Quality Assurance	New Technology	N	Y	Y	0%
Process and Product Quality Assurance	Business Focus	N	N	N	100%
Process and Product Quality Assurance	Market Intelligence	N	N	N	100%

Table 6-12: Other Process Area/Benefit combinations of PPQA

In summary, of the 17 Process Area/Benefit combinations for PPQA:

- 8 combinations are 100% compliant
- 4 combinations are 50% compliant

- 5 combinations are 0% compliant.

There were 4 combinations which were 50% compliant with interviewees' experiences. For the relationship between PPQA and *Competitive Proposals*, the second interviewee is of the opinion that there is a positive relationship between both. His reasoning behind this is that, especially in a highly regulated environment, if an organization does not implement PPQA, clients may not even accept your bid. In many cases in a highly regulated environment, a proposal can come down to certification and quality – a competitive bid is more than just having the right financials compared to your competitors. The second interviewee is also of the opinion that there is a positive relationship between PPQA and PPQA and *Retain and Develop Skills and Domain Knowledge* because all process involves a build-up of the knowledge base. This knowledge base can then help people move more easily in to a new position.

There were 5 combinations which were 0% compliant with expectations. From the interviews, both feel that, while they have no specific evidence and experience in their practices, to support their positions, they feel that logically there is a positive relationship between PPQA and *Skill Development Facilitation By Management*, *Efficient Information Management, Teaming/Synergize, New Technology* and *Business Focus* whereas the model stated that there was no relationship.

6.2.7 Configuration Management

Process Area	**IGSI-ISM Benefit**	**RS-ICMMI Model**	**Interviewee 1 Results**	**Interviewee 2 Results**	**Compliance to RS-ICMMI**
Configuration Management	Teaming/Synergize (6-3)	Y	Y	Y	100%
Configuration Management	Better Quality Product (4-1)	Y	Y	Y	100%
Configuration Management	Better Risk Management (4-2)	Y	Y	Y	100%

Table 6-13: Primary benefits of CM

All the responses for Configuration Management (CM) are 100% compliant interviewees' experiences. The second interviewee had specific evidence on the relationships between CM and *Better Quality Product* and *Better Risk Management*. For *Better Quality Product*, he has seen where teams "don't like using configuration management but, unless they do, things fall apart from an efficiency and productivity perspective." With regards to *Better Risk*

Management, Configuration Management reduces waste of time and resources. The first interviewee also agrees with the relationship and cites an increase in productivity and an increase in positive communications as a result of implementation, which both act to reduce risk.

In summary, of the 18 Process Area/Benefit combinations for CM:

- 11 combinations are 100% compliant
- 4 combinations are 50% compliant
- 3 combination is 0% compliant.

There were 4 combinations which were 50% compliant with interviewees' experiences. The first interviewee found that there is a positive relationship between CM and *Skill Development Facilitation By Management* and was of the opinion that the relationship was strong and is not given as much attention as it deserves. The remaining items were the logical opinions of the interviewees and they had no specific evidence to support their assertions.

There were 3 combinations which were 0% compliant with expectations. The interviewees could not offer any evidence of their assertions on the cause and effect relationships between CM and *Predictability*, and *Efficient Information Management* from either specific experience or general experience in practice.

Process Area	**IGSI-ISM Benefit**	**RS-ICMMI Model**	**Interviewee 1 Results**	**Interviewee 2 Results**	**Compliance to RS-ICMMI**
Configuration Management	Increased Revenues/Profits	Y	Y	Y	100%
Configuration Management	Image	Y	Y	Y	100%
Configuration Management	Higher Customer Satisfaction	Y	Y	Y	100%
Configuration Management	Market Reach	Y	Y	Y	100%
Configuration Management	Increased Productivity	Y	Y	Y	100%
Configuration Management	Setting right Customer Expectations	Y	Y	Y	100%
Configuration Management	Predictability	Y	Y	Y	100%
Configuration Management	Competitive Proposals	N	Y	Y	0%
Configuration Management	Efficient Resource Management	Y	Y	Y	100%

Process Area	IGSI-ISM Benefit	RS-ICMMI Model	Interviewee 1 Results	Interviewee 2 Results	Compliance to RS-ICMMI
Configuration Management	Retain & Develop Skills & Domain Knowledge	Y	Y	N	50%
Configuration Management	Lower Time to Market	Y	Y	Y	100%
Configuration Management	Skill Development Facilitation by Management	N	Y	N	50%
Configuration Management	Efficient Information Management	N	Y	Y	0%
Configuration Management	New Technology	N	Y	N	50%
Configuration Management	Improved Institutionalization of tools / process / methods	N	Y	N	50%
Configuration Management	Business Focus	N	N	N	100%
Configuration Management	Market Intelligence	N	N	N	100%

Table 6-14: Other Process Area/Benefit combinations of CM

6.3 Updated RS-ICMMI Model

In summary, according to the model, there were expected to be 31 PA/Benefit combinations which would yield primary benefits. As a result of the interviews, 28 combinations were 100% in compliance with expectations, with a further 3 being 50% compliant with expectations. In addition, there were 4 PA/Benefit combinations which were not defined in the model as having a primary impact but which have been identified through the interviews with experts. Of these 4, only 1 had 100% agreement from the interviewees and is therefore the only one which has been upgraded to a primary impact.

From a secondary benefits perspective, according to the model there are a total of 123 PA/Benefit combinations. Of the 123 combinations, 73 are 100% compliant, 33 are 50% compliant, and 15 are 0% compliant. On a strict compliance basis, the model correctly predicted approximately 60% of the potential secondary PA/Benefits. If, on the hand, we give equal weight to the model and each interviewee, that number rises to approximately 87% (73 answers are 100% compliant and 33 are 50% compliant).

Based on the feedback from the interviewees, the RS-ICMMI mapping instance was revised. As noted in section 6.2, when a response is 0% compliant with expectations, both interviewees disagree with the initial mapping. In such cases, the initial mapping was modified to reflect the opinions of the interviewees. These modifications led to both additions to the mapping as well subtraction from the original mapping. In the cases where, in the original mapping, there was not a link between a Process Area and a Benefit but both interviewees have presented evidence to the contrary, it was added into the mapping. In the cases where, in the original mapping, a link between a Process Area and a Benefit was included but where both interviewees could not present evidence that such a relationship should exist, the mapping was removed. In addition, after the individual mappings were either added or removed from the RS-ICMMI benefits map, a further analysis was performed to either add in or remove any derived benefits. Table 6-15 summarizes the changes while Table 6-16 through to Table 6-22 contain the new, modified mapping.

Process Area	Benefit Type	Action	Mapping
REQM	Primary	Addition	Predictability (3-4)
REQM	Secondary	Addition	Increased Productivity (3-2), Better Quality Product (4-1), Skill Development Facilitation by Management (7-3)
REQM	Secondary	Removal	Market Intelligence (7-3)
PMC	Secondary	Addition	Competitive Proposals (3-5)
SAM	Secondary	Addition	Efficient Resource Management (4-3), Efficient Information Management (6-2)
MA	Secondary	Addition	Improved Institutionalization of Process/Tools/Methods (7-1)
MA	Secondary	Removal	Market Reach (3-1)
PPQA	Secondary	Addition	Efficient Information Management (6-2), Teaming/Synergize (6-3), New Technology (6-4), Skill Development Facilitation by Management (7-3)
CM	Secondary	Addition	Competitive Proposals (3-5), Efficient Information Management (6-2)

Table 6-15: Summary of post-validation changes to RS-ICMMI mapping

Expected Primary Benefits	Expected Secondary Benefits
• Lower Time to Market (5-2) • Better Risk Management (4-2) • Understanding Customer Needs (4-4) • Predictability (3-4)	• Skill Development Facilitation by Management (6-1) • Retain & Develop Skills & Domain Knowledge (5-1) • Better Quality Product (4-1) • Efficient Resource Management (4-3) • Increased Productivity (3-2) • Predictability (3-4) • Competitive Proposals (3-5) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)

Table 6-16: Post-validation REQM benefits mapping

Expected Primary Benefits	Expected Secondary Benefits
• Better Quality Product (4-1) • Better Risk Management (4-2) • Efficient Resource Management (4-3) • Understanding Customer Needs (4-4) • Setting Right Customer Expectations (3-3) • Predictability (3-4) • Competitive Proposals (3-5)	• Market Reach (3-1) • Increased Productivity (3-2) • Predictability (3-4) • Competitive Proposals (3-5) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)

Table 6-17: Post-validation PP benefits mapping

Expected Primary Benefits	Expected Secondary Benefits
• Better Quality Product (4-1) • Better Risk Management (4-2) • Efficient Resource Management (4-3) • Setting Right Customer Expectations (3-3) • Predictability (3-4)	• Market Reach (3-1) • Increased Productivity (3-2) • Competitive Proposals (3-5) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)

Table 6-18: Post-validation PMC benefits mapping

Expected Primary Benefits	Expected Secondary Benefits
• Lower Time To Market (5-2) • Better Quality Product (4-1) • Better Risk Management (4-2) • Predictability (3-4)	• Efficient Information Management (6-2) • Retain & Develop Skills and Domain Knowledge (5-1) • Efficient Resource Management (4-3) • Market Reach (3-1) • Increased Productivity (3-2) • Setting Right Customer Expectations (3-3) • Predictability (3-4) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)

Table 6-19: Post-validation SAM benefits mapping

Expected Primary Benefits	Expected Secondary Benefits
• Lower Time To Market (5-2) • Better Quality Product (4-1) • Better Risk Management (4-2) • Predictability (3-4)	• Improved Institutionalization of Tools/Process/Methods (7-1) • Skill Development Facilitation by Management (6-1) • Efficient Information Management (6-2) • Retain & Develop Skills & Domain Knowledge (5-1) • Increased Productivity (3-2) • Setting Right Customer Expectations (3-3) • Predictability (3-4) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)

Table 6-20: Post-validation MA benefits mapping

Expected Primary Benefits	Expected Secondary Benefits
• Improved Institutionalization of tools/process/methods (7-1) • Lower Time To Market (5-2) • Better Quality Product (4-1) • Better Risk Management (4-2) • Predictability (3-4)	• Skill Development Facilitation by Management (6-1) • Effective Information Management (6-2) • Teaming/Synergize (6-3) • New Technology (6-4) • Retain & Develop Skills & Domain Knowledge (5-1) • Efficient Resource Management (4-3) • Understanding Customer Needs (4-4) • Market Reach (3-1) • Increased Productivity (3-2) • Setting Right Customer Expectations (3-3) • Predictability (3-4) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)

Table 6-21: Post-validation PPQA benefits mapping

Expected Primary Benefits	Expected Secondary Benefits
• Teaming/Synergize (6-3) • Better Quality Product (4-1) • Better Risk Management (4-2) •	• Efficient Information Management (6-2) • Retain & Develop Skills & Domain Knowledge (5-1) • Lower Time To Market (5-2) • Efficient Resource Management (4-3) • Understanding Customer Needs (4-4) • Market Reach (3-1) • Increased Productivity (3-2) • Setting Right Customer Expectations (3-3) • Predictability (3-4) • Competitive Proposals (3-5) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)

Table 6-22: Post-validation CM benefits mapping

6.4 Conclusion

As a result of the validation, an updated model of the RS-ICMMI mapping instance is presented. For mappings which were either 100% compliant or 50% with expectations, no change was made to the RS-ICMMI mapping. For those mappings which were 0% compliant with expectations, the mapping was altered to reflect the opinions of the interviewees. This validation was completed for CMMI (Staged) Level 2 only.

7 Summary and Conclusions

7.1 Introduction

This chapter summarizes the main findings of this dissertation, outlines its contribution to the field, and suggests potential areas for future research. To do this, I revisited the Research Objective and the Research Methodology used as well as the process by which the research was conducted. After this, the limitations of the research are reviewed thus placing the next section, Summary of Findings and Conclusions, into context. Finally, while the result of this research is a methodology for a business benefit driven approach to SPI as well as a concrete example of how this methodology can be used in practice, it has also shone the light on potential areas for future research, including some questions which arose as part of the research. These are explored in the section on Opportunities for Future Research.

7.2 Research Question

While well-known SPI methodologies exist, e.g. CMMI (SEI 2002a; 2002b; 2006), ISO/IEC 15504 (SPICE) (ISO 2004a), ISO-9000-3 (ISO 1994), they are IT-driven in that they aim to improve software processes from a purely IT perspective without any specific drivers that would be considered to be business-driven such as productivity improvement, minimization of time to market, and maximization of profit.

The purpose of this research was to develop and evaluate a generic methodology that allows organizations to achieve specific business-focused objectives by implementing various existing and proven SPIs. While a business-driven approach to SPI is novel and research-worthy in itself, in order for such a model to be successful in the real world it should be flexible enough to be able to support the sometimes vastly different organizational objectives of various types of businesses – government organizations, non-government organizations (NGOs), the military, and for-profit commercial companies to name but a few. Not only should it be flexible enough to support these various organization types, but it should also be customizable so that individual organizations are able to customize benefit models. In addition, as an enormous amount of effort has been spent on SPI and SPI research, any proposed model should leverage existing work as much as possible.

In order to meet these objectives the Rosetta Stone Methodology was developed which meets all these requirements. It is a generic benefits-driven methodology which, in its essence, allows practitioners to map from a benefits model which is appropriate to a particular organization to a proven SPI methodology. In addition, is it fully customizable and allows organizations to make adjustments to the implementation instance where they feel it appropriate. In summary, to quote from Chapter 3, the research objective is:

> *To develop and evaluate a methodology that allows organizations to achieve specific organization-pertinent benefits using existing SPI methodologies and techniques.*

7.3 Critical Review of Research

7.3.1 Critical Review of Research Approach and Philosophy

As discussed in Chapter 3, the research approach to this work is constructionist, interpretivist, and qualitative in nature. For any approach, there are arguments for and against. This is no less true for the constructionist, interpretivist, and qualitative paradigms than for any other paradigm.

From an epistemological perspective, constructionism is in direct opposition to positivism. Contructionism holds that there is no single valid methodology and that scientific knowledge is constructed by scientists, not taken from the world. Positivism, on the other hand, holds that affirmation of theories can only come through strict scientific methods – quantitative methods. Interpretivism, in loose terms, is the view that one can understand an area by studying what people think about the area. Positivism, as we have seen, is the primary philosophy behind what we in the Western world understand as the scientific method. It involves treating the world as a set of concrete entities with discrete measurements that have cause and effect relationships.

While other research frequently builds on top of previous research to further our knowledge, this research is a branch off from previous research and so is quite unlike previous work done in this field. As a result, there is no vast body of knowledge that can be leveraged in order to provide affirmation (or contradiction) of the research. Instead we are forced to rely on people's industrial experiences and background to determine the validity of the research. Not only that, but there is a limited amount of people who can provide this input for various reasons. Therefore while the research presented in this thesis does not follow a positivist/quantitative philosophy, the approach followed qualitative research guidelines and therefore the results presented can be recognized as valid.

7.3.2 Critical Review of Research Contribution

Central to any research work is the establishment of the trustworthiness or validity of the report itself. Lincoln and Guba (1985) suggest four questions which can be used to evaluate the trustworthiness of a report:

1. Truth Value – can the report we relied upon to provide the "truth" in relation to the findings of the report in the context of the research?
2. Applicability – to what extent are the findings generalizable and applicable to other contexts?
3. Consistency – to what extent would another report produce the same results?
4. Neutrality – to what extent is the report absent of bias (intentional or otherwise), interests, or perspectives of the person writing the report?

Within the context of this thesis two distinct phases of research were undertaken – research of the validity and applicability of the Rosetta Stone Methodology and the validation of the mapping of the RS-ICMMI. In order to arrive at a balanced, critical review of the research process for this thesis, including threats to the validity of the work, both phases will be evaluated individually in relation to the questions posed by Lincoln and Guba.

Critical Review of the Validation of the Rosetta Stone Methodology

The research process for the validation of the Rosetta Stone Methodology may be summarized as being interpretivist in nature, using an expert panel to analyse the validity of the proposed methodology. The interviews were then analysed using content analysis techniques. The expert panel members came primarily from three disparate sources – IT professionals who have used CMMI extensively; peers in various organizations which practice some form of SPI; and several academics who have a professional and academic interest in SPI. Based on these sources, it could be argued that many of the interviewees have an in-built bias in favour of SPI. As the proposed methodology is quite different from other methodologies which have been proposed, there was very little basis on which to ask the members to compare one methodology against another. As a result, many of the questions were purposefully open-ended, allowing them to provide answers which could provide more depth and insight than if closed-ended questions were asked. Due to the open-ended nature of the answers, widely-used content analysis techniques were employed to analyse the results.

While there were several panel members who admitted to either working or having worked in organizations where there was scepticism of SPI, many of the panel members had an in-built positive disposition towards SPI. As a result, from a truth value perspective, criticism could be levelled at the research that there may be an in-built bias towards the positive aspects of SPI. However, this is also reflected in the literature where there are relatively fewer negative SPI articles than positive ones. As this is a general methodology, it should have a high level of applicability. From a consistency perspective, as a lot of the questions posed to the panel members were open ended there is no guarantee that, given the same interview at a different time, there would not be a different answer. That is not to say, however, that the answers panel members gave in the interviews were incorrect or misleading – it might just be that, given a different stimulus from whatever source, the answer might be taken down a different path. It is extremely difficult for humans to be totally neutral in their thoughts and ideas – everyone has their own built-in biases which they may not even be aware of. However, in an attempt to avoid this problem, the interviews were all pre-scripted, recorded, and analysed consistently so, within the context of what was actually asked, the results of the interviews are expected to be neutral.

Critical Review of the Validation of RS-ICMMI

The research process for the validation of the RS-ICMMI mapping consisted of a set of very tightly scripted mapping questions and, for each mapping question, an open ended question where the interviewee was asked if he or she had any particular evidence to support the mapping question. The results were then analyzed empirically.

Again, as was the case for the validation phase of the Rosetta Stone Methodology, the population of members of the expert panel came from a group of professionals who, in many cases, would be expected to be biased in favour of SPI. As a result, from a truth value perspective, criticism could also be levelled at this phase of the research that there may be an in-built bias towards the positive aspects of SPI. The RS-ICMMI mapping is a specific application of the generic Rosetta Stone Methodology. In particular, it depends heavily on the IGSI-ISM benefits model. As a result, a possible criticism of the RS-ICMMI mapping is that, because it is closely coupled the IGSI-ISM benefits model, it could be seen to lack generalizability. With regard to consistency, while there was a substantial number of experts in the expert panel available for the research, due to the large volume of questions which needed to be answered, each mapping was put to only two expert panel members. From a statistical analysis perspective, larger populations samples tend to provide a more accurate reflection of the domain being studied and an extension of the study would increase the consistency of the result. With regard to neutrality, as the mapping questions were binary in nature, and not as open-ended as in the first phase, this phase of the research would seem to be more neutral than the previous phase.

7.3.3 Other Limitations

This research is primarily focused on the creation of a methodology to support business-driven SPI, as well as one particular instance of that mapping using CMMI and the IGSI-ISM benefits model. As a result of this narrow focus, there are several other remaining interesting research areas which could be addressed in future research in order to increase the generalizability of the work. These areas are addressed in section 7.5. However, probably the main limitation of this research is the fact that the RS-ICMMI mapping has not been used in industry to verify that it works as anticipated. While there are legitimate reasons why it has not been implemented and these have been discussed earlier, the ultimate proof of its validity would be the implementation of it in practice to achieve specific business objectives.

7.4 Summary of Findings and Contribution

The Rosetta Stone Methodology and an implementation instance of the methodology, the RS-ICMMI implementation instance, are presented in this work. Through a literature review, it was established that no business-driven SPI methodology was readily available. The Rosetta Stone Methodology and the RS-ICMMI mapping instance was then developed using a literature review, GQM, and an informal review by fellow professionals by combining an existing business objectives model, the IGSI-ISM benefits model, and CMMI. To validate the Rosetta Stone Methodology, a series of expert panel interviews was carried out with SPI experts. The response to the methodology has been positive with many of the interviewees expressing interest in potentially using the approach discussed in this thesis. The meta-model and methodology was universally approved by the interviewees without negative comment, while the only major comments on the IGSI-ISM benefits model to CMMI (Staged) mapping were on possible customizations to the IGSI-ISM benefits model, which is in any case catered for by the model itself. The RS-ICMMI mapping instance was validated using an expert panel and relevant changes were made to the mapping as a result of the validation process.

Literature and potential methodologies/models in the chosen area are quite sparse. As we shall see in the next section, this whole area is ripe for research and commercial exploitation. That is not to say, however, that the methodology developed for this dissertation is perfect and is readily usable by practitioners; in fact, far from it. To date no organization has implemented either the methodology or the RS-ICMMI mapping instance and, while intellectually the methodology may appear to make sense, there is potentially a very large gap between a theoretical methodology and a practical (and useful) implementation of that methodology.

7.5 Opportunities for Future Research

The entire area of an organization-driven objectives approach to SPI is novel and, as a result, has not been explored to any degree. Consequently, there are many opportunities for future research. As with the methodology itself, the opportunities for future research can be characterized along the lines of those opportunities which result from open questions or clarifications on the generic methodology and open questions or clarifications arising from the mapping from the IGSI-ISM benefits model to CMMI (Staged).

7.5.1 Opportunities for Future Research – Rosetta Stone Methodology

The Rosetta Stone Methodology allows an arbitrary benefits/objectives model to be mapped to an arbitrary SPI methodology. As a demonstration of this, a mapping was developed between a benefits model developed by IBM in India and CMMI (Staged). As IBM is a commercial organization and the division in question was a consulting services organization, the focus on the benefits was primarily on commercial benefits with a bias towards consulting services. There are many other different types of organization – NGOs, military, and government organizations to name but a few – which each have their own organizational drivers. It is highly unlikely that these organizations would have the same drivers as the IGSI-ISM model so the whole area of developing generic objective/driver models for these organizations would be of tremendous interest to them, especially if the IGSI-ISM to CMMI mapping is undertaken by a commercial organization and proves to be of benefit.

Another area for potential future research is on the IGSI-ISM model itself and to perhaps incorporate changes to the model. Indeed, as noted in section 5.4.3, some minor changes to the model were suggested by the participants in the interview process and these changes have been incorporated in Figure 7-1.

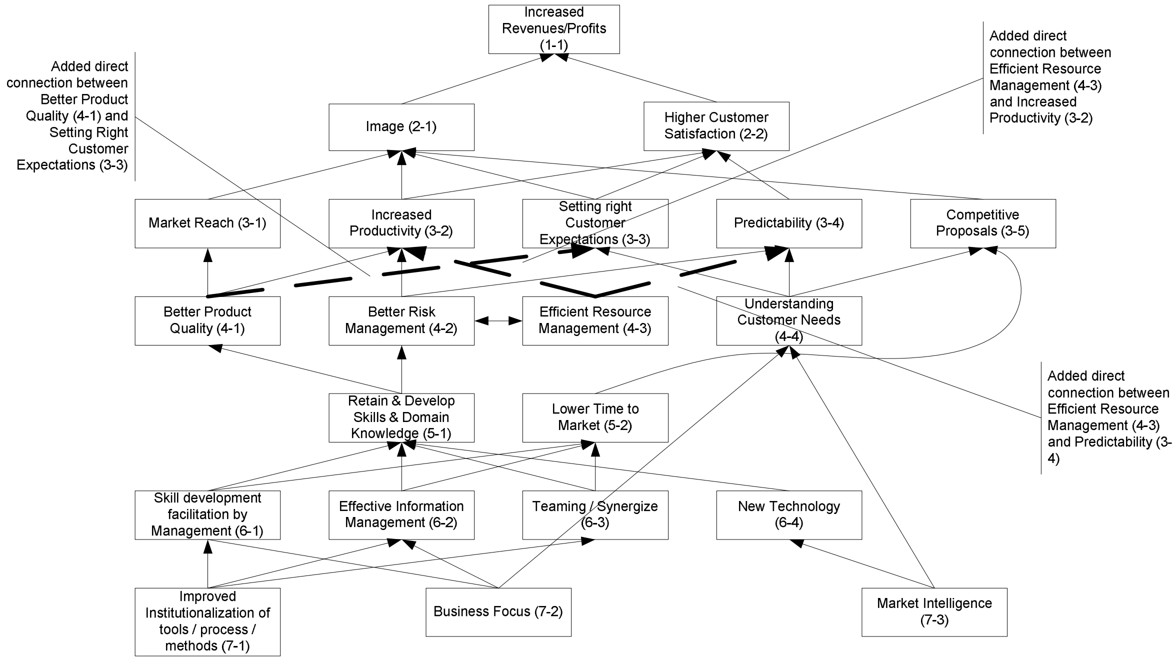

Figure 7-1: Modified IGSI-ISM model

In a similar vein, one of the interviewees in the expert panel interviews suggested a model based on the Project Management Triangle:

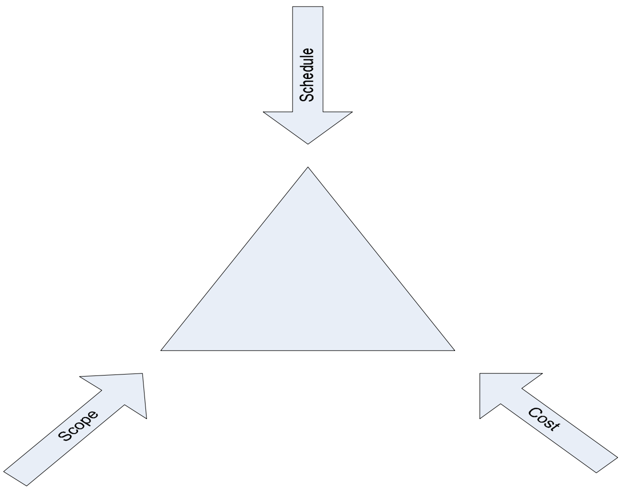

Figure 7-2: Project Management Triangle

The idea would be to have one benefits model for each of the constraints – Cost, Scope, and Schedule. As this is a generic project management constraint model, it could potentially be used by organizations, primarily software houses, whose main business is in software development. This would not obviously address operational issues such as support of existing systems.

As we have seen in Chapter 2, CMM/CMMI has gone through a gradual evolution from the original CMM (SW) implementation which was a staged model through to the generic CMMI model which is now available in either a Staged or a Continuous model. Concurrently, the ISO/IEC 15504 model has been developed and is continuous in nature. In addition, it seems that a continuous approach offers a lot more flexibility than the traditional staged models. It would not be unexpected, therefore, that future evolutions of CMMI will move more and more towards a continuous approach, up to the point where it is conceivable that a staged approach may in fact be totally dropped from their offerings. While it may be useful to explore various other SPI methodologies from a generic methodology perspective, I would suggest that the next one to be mapped should be the CMMI (Continuous) model.

7.5.2 Opportunities for Future Research – RS-ICMMI mapping

Many of the areas for potential future research within the concrete demonstration mapping arise from the limitations already described within the research methodology and the results of the expert panel interviews.

The first, and probably most critical, area for future research based on the mapping would be to implement it within a commercially focused organization who could easily customize (if required) the IGSI-ISM benefits/objectives model to their own organization. The successful implementation of the mapping would prove to usefulness of this approach. Failing a full implementation, a limited-scope implementation would be the next-best thing, again helping to demonstrate the usefulness of the Rosetta Stone Methodology.

In addition, as this work validated the RS-ICMMI mapping for CMMI (Staged) Level 2 only, it may be worthwhile to validate the remaining CMMI Levels – 3, 4, and 5.

7.6 Conclusion

This research set out to both develop and evaluate a business-driven approach to SPI. As a result, a new methodology and a new instance mapping were developed – the Rosetta Stone Methodology and the concrete RS-ICMMI model which maps from the IGSI-ISM business-focused benefits model to the CMMI (Staged) SPI model. Both the methodology and the instance mapping were then reviewed and evaluated by a set of experts in both the software life cycle and SPI. Based on their evaluation, both the methodology and the instance mapping constitute a valid and practical approach to a business-driven approach to SPI. As a result, both primary objectives of this research have been successfully accomplished.

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Appendixes

Appendix A Full CMMI (Staged) to IGSI-ISM Mapping

Level 2 Mapping

Process Area	Expected Primary Benefits	Expected Secondary Benefits
Requirements Management	Better Risk Management (4-2)	Market Intelligence (7-3)
Requirements Management	Understanding Customer Needs (4-4)	Retain & Develop Skills & Domain Knowledge (5-1)
Requirements Management	Lower Time to Marker (5-2)	Efficient Resource Management (4-3)
Requirements Management		Predictability (3-4)
Requirements Management		Competitive Proposals (3-5)
Requirements Management		Image (2-1)
Requirements Management		Higher Customer Satisfaction (2-2)
Requirements Management		Increased Revenues/Profits (1-1)
Process Area	**Expected Primary Benefits**	**Expected Secondary Benefits**
Project Planning	Better Quality Product (4-1)	Market Reach (3-1)
Project Planning	Better Risk Management (4-2)	Increased Productivity (3-2)
Project Planning	Predictability (3-4)	Predictability (3-4)
Project Planning	Setting Right Customer Expectations (3-3)	Competitive Proposals (3-5)
Project Planning	Competitive Proposals (3-5)	Image (2-1)
Project Planning	Efficient Resource Management (4-3)	Higher Customer Satisfaction (2-2)
Project Planning	Understanding Customer Needs (4-4)	Increased Revenues/Profits (1-1)
Process Area	**Expected Primary Benefits**	**Expected Secondary Benefits**
Project Monitoring and Control	Better Quality Product (4-1)	Market Reach (3-1)
Project Monitoring and Control	Better Risk Management (4-2)	Increased Productivity (3-2)
Project Monitoring and Control	Efficient Resource Management (4-3)	Image (2-1)
Project Monitoring and Control	Setting Right Customer Expectations (3-3)	Higher Customer Satisfaction (2-2)
Project Monitoring and Control	Predictability (3-4)	Increased Revenues/Profits (1-1)

Process Area	Expected Primary Benefits	Expected Secondary Benefits
Supplier Agreement Management	Lower Time To Market (5-2)	Market Reach (3-1)
Supplier Agreement Management	Better Quality Product (4-1)	Increased Productivity (3-2)
Supplier Agreement Management	Better Risk Management (4-2)	Setting Right Customer Expectations (3-3)
Supplier Agreement Management	Predictability (3-4)	Predictability (3-4)
Supplier Agreement Management		Image (2-1)
Supplier Agreement Management		Higher Customer Satisfaction (2-2)
Supplier Agreement Management		Increased Revenues/Profits (1-1)
Process Area	**Expected Primary Benefits**	**Expected Secondary Benefits**
Measurement and Analysis	Lower Time To Market (5-2)	Market Reach (3-1)
Measurement and Analysis	Better Quality Product (4-1)	Increased Productivity (3-2)
Measurement and Analysis	Better Risk Management (4-2)	Setting Right Customer Expectations (3-3)
Measurement and Analysis	Predictability (3-4)	Predictability (3-4)
Measurement and Analysis		Image (2-1)
Measurement and Analysis		Higher Customer Satisfaction (2-2)
Measurement and Analysis		Increased Revenues/Profits (1-1)

Process Area	Expected Primary Benefits	Expected Secondary Benefits
Process and Product Quality Assurance	Improved Institutionalization of tools/process/methods (7-1)	Skill development facilitation by management (6-1)
Process and Product Quality Assurance	Lower Time To Market (5-2)	Effecitive Information Management (6-2)
Process and Product Quality Assurance	Better Quality Product (4-1)	Teaming/Synergize (6-3)
Process and Product Quality Assurance	Better Risk Management (4-2)	Retain & Develop Skills & Domain Knowledge (5-1)
Process and Product Quality Assurance	Predictability (3-4)	Efficient Resource Management (4-3)
Process and Product Quality Assurance		Understanding Customer Needs (4-4)
Process and Product Quality Assurance		Market Reach (3-1)
Process and Product Quality Assurance		Increased Productivity (3-2)
Process and Product Quality Assurance		Setting Right Customer Expectations (3-3)
Process and Product Quality Assurance		Predictability (3-4)
Process and Product Quality Assurance		Image (2-1)
Process and Product Quality Assurance		Higher Customer Satisfaction (2-2)
Process and Product Quality Assurance		Increased Revenues/Profits (1-1)

Process Area	Expected Primary Benefits	Expected Secondary Benefits
Configuration Management	Teaming/Synergize (6-3)	Retain & Develop Skills & Domain Knowledge (5-1)
Configuration Management	Better Quality Product (4-1)	Lower Time To Market (5-2)
Configuration Management	Better Risk Management (4-2)	Efficient Resource Management (4-3)
Configuration Management		Understanding Customer Needs (4-4)
Configuration Management		Market Reach (3-1)
Configuration Management		Increased Productivity (3-2)
Configuration Management		Setting Right Customer Expectations (3-3)
Configuration Management		Predictability (3-4)
Configuration Management		Image (2-1)
Configuration Management		Higher Customer Satisfaction (2-2)
Configuration Management		Increased Revenues/Profits (1-1)

Level 3 Mapping

Process Area	Expected Benefits	Expected Secondary Benefits
Requirements Development	Lower Time To Market (5-2)	Efficient Resource Management (4-3)
Requirements Development	Better Quality Product (4-1)	Market Reach (3-1)
Requirements Development	Better Risk Management (4-2)	Increased Productivity (3-2)
Requirements Development	Understanding Customer Needs (4-4)	Setting Right Customer Expectations (3-3)
Requirements Development		Predictability (3-4)
Requirements Development		Competitive Proposals (3-5)
Requirements Development		Image (2-1)
Requirements Development		Higher Customer Satisfaction (2-2)
Requirements Development		Increased Revenues/Profits (1-1)
Process Area	Improved Institutionalization of tools/process/methods (7-1)	Skill development facilitation by Management (6-1)
Organizational Process Focus	Business Focus (7-2)	Effective Information Management (6-2)
Organizational Process Focus	Market Intelligence (7-3)	Teaming / Synergize (6-3)
Organizational Process Focus		New Technology (6-4)
Organizational Process Focus		Retain & Develop Skills & Domain Knowledge (5-1)
Organizational Process Focus		Lower Time to Market (5-2)
Organizational Process Focus		Better Quality Product (4-1)
Organizational Process Focus		Better Risk Management (4-2)
Organizational Process Focus		Efficient Resource Management (4-3)
Organizational Process Focus		Understanding Customer Needs (4-4)
Organizational Process Focus		Market Reach (3-1)
Organizational Process Focus		Increased Productivity (3-2)
Organizational Process Focus		Setting Right Customer Expectations (3-3)
Organizational Process Focus		Predictability (3-4)
Organizational Process Focus		Competitive Proposals (3-5)
Organizational Process Focus		Image (2-1)
Organizational Process Focus		Higher Customer Satisfaction (2-2)
Organizational Process Focus		Increased Revenues / Profits (1-1)

Process Area	Expected Primary Benefits	Expected Secondary Benefits
Organizational Process Definition	Improved Institutionalization of tools/process/methods (7-1)	Skill development facilitation by Management (6-1)
Organizational Process Definition	Effective Information Management (6-2)	Teaming / Synergize (6-3)
Organizational Process Definition		Retain & Develop Skills & Domain Knowledge (5-1)
Organizational Process Definition		Lower Time to Market (5-2)
Organizational Process Definition		Better Quality Product (4-1)
Organizational Process Definition		Better Risk Management (4-2)
Organizational Process Definition		Efficient Resource Management (4-3)
Organizational Process Definition		Understanding Customer Needs (4-4)
Organizational Process Definition		Market Reach (3-1)
Organizational Process Definition		Increased Productivity (3-2)
Organizational Process Definition		Setting Right Customer Expectations (3-3)
Organizational Process Definition		Predictability (3-4)
Organizational Process Definition		Competitive Proposals (3-5)
Organizational Process Definition		Image (2-1)
Organizational Process Definition		Higher Customer Satisfaction (2-2)
Organizational Process Definition		Increased Revenues / Profits (1-1)

Process Area	Expected Primary Benefits	Expected Secondary Benefits
Organizational Training	Skill development facilitation by Management (6-1)	Retain & Develop Skills & Domain Knowledge (5-1)
Organizational Training	Teaming / Synergize (6-3)	Lower Time to Market (5-2)
Organizational Training		Better Quality Product (4-1)
Organizational Training		Better Risk Management (4-2)
Organizational Training		Efficient Resource Management (4-3)
Organizational Training		Understanding Customer Needs (4-4)
Organizational Training		Market Reach (3-1)
Organizational Training		Increased Productivity (3-2)
Organizational Training		Setting Right Customer Expectations (3-3)
Organizational Training		Predictability (3-4)
Organizational Training		Competitive Proposals (3-5)
Organizational Training		Image (2-1)
Organizational Training		Higher Customer Satisfaction (2-2)
Organizational Training		Increased Revenues / Profits (1-1)

Process Area	Expected Primary Benefits	Expected Secondary Benefits
Technical Solution	Better Quality Product (4-1)	Market Reach (3-1)
Technical Solution	Better Risk Management (4-2)	Increased Productivity (3-2)
Technical Solution	Efficient Resource Management (4-3)	Setting Right Customer Expectations (3-3)
Technical Solution	Understanding Customer Needs (4-4)	Predictability (3-4)
Technical Solution		Competitive Proposals (3-5)
Technical Solution		Image (2-1)
Technical Solution		Higher Customer Satisfaction (2-2)
Technical Solution		Increased Revenues / Profits (1-1)
Process Area	**Expected Primary Benefits**	**Expected Secondary Benefits**
Integrated Project Management for IPPD	Teaming / Synergize (6-3)	Retain & Develop Skills & Domain Knowledge (5-1)
Integrated Project Management for IPPD	Better Quality Product (4-1)	Lower Time to Market (5-2)
Integrated Project Management for IPPD	Better Risk Management (4-2)	Market Reach (3-1)
Integrated Project Management for IPPD	Efficient Resource Management (4-3)	Increased Productivity (3-2)
Integrated Project Management for IPPD	Understanding Customer Needs (4-4)	Setting Right Customer Expectations (3-3)
Integrated Project Management for IPPD		Predictability (3-4)
Integrated Project Management for IPPD		Competitive Proposals (3-5)
Integrated Project Management for IPPD		Image (2-1)
Integrated Project Management for IPPD		Higher Customer Satisfaction (2-2)
Integrated Project Management for IPPD		Increased Revenues / Profits (1-1)

Process Area	Expected Primary Benefits	Expected Secondary Benefits
Integrated Teaming	Effective Information Management (6-2)	Retain & Develop Skills & Domain Knowledge (5-1)
Integrated Teaming	Teaming / Synergize (6-3)	Lower Time to Market (5-2)
Integrated Teaming	Better Quality Product (4-1)	Market Reach (3-1)
Integrated Teaming	Better Risk Management (4-2)	Increased Productivity (3-2)
Integrated Teaming	Efficient Resource Management (4-3)	Setting Right Customer Expectations (3-3)
Integrated Teaming	Understanding Customer Needs (4-4)	Predictability (3-4)
Integrated Teaming		Competitive Proposals (3-5)
Integrated Teaming		Image (2-1)
Integrated Teaming		Higher Customer Satisfaction (2-2)
Integrated Teaming		Increased Revenues / Profits (1-1)
Process Area	**Expected Primary Benefits**	**Expected Secondary Benefits**
Integrated Supplier Management	Business Focus (7-2)	Retain & Develop Skills & Domain Knowledge (5-1)
Integrated Supplier Management	Market Intelligence (7-3)	Lower Time to Market (5-2)
Integrated Supplier Management	Teaming / Synergize (6-3)	Efficient Resource Management (4-3)
Integrated Supplier Management	New Technology (6-4)	Market Reach (3-1)
Integrated Supplier Management	Lower Time to Market (5-2)	Increased Productivity (3-2)
Integrated Supplier Management	Better Quality Product (4-1)	Setting Right Customer Expectations (3-3)
Integrated Supplier Management	Better Risk Management (4-2)	Competitive Proposals (3-5)
Integrated Supplier Management	Predictability (3-4)	Image (2-1)
Integrated Supplier Management		Higher Customer Satisfaction (2-2)
Integrated Supplier Management		Increased Revenues / Profits (1-1)

Process Area	Expected Primary Benefits	Expected Secondary Benefits
Organizational Environment for Integration	Improved Institutionalization of tools/process/methods (7-1)	Skill development facilitation by Management (6-1)
Organizational Environment for Integration	Business Focus (7-2)	New Technology (6-4)
Organizational Environment for Integration	Effective Information Management (6-2)	Retain & Develop Skills & Domain Knowledge (5-1)
Organizational Environment for Integration	Teaming / Synergize (6-3)	Lower Time to Market (5-2)
Organizational Environment for Integration	Lower Time to Market (5-2)	Better Quality Product (4-1)
Organizational Environment for Integration		Better Risk Management (4-2)
Organizational Environment for Integration		Efficient Resource Management (4-3)
Organizational Environment for Integration		Understanding Customer Needs (4-4)
Organizational Environment for Integration		Market Reach (3-1)
Organizational Environment for Integration		Increased Productivity (3-2)
Organizational Environment for Integration		Setting Right Customer Expectations (3-3)
Organizational Environment for Integration		Predictability (3-4)
Organizational Environment for Integration		Competitive Proposals (3-5)
Organizational Environment for Integration		Image (2-1)
Organizational Environment for Integration		Higher Customer Satisfaction (2-2)
Organizational Environment for Integration		Increased Revenues / Profits (1-1)

Process Area	**Expected Primary Benefits**	**Expected Secondary Benefits**
Product Integration	Better Quality Product (4-1)	Market Reach (3-1)
Product Integration	Better Risk Management (4-2)	Increased Productivity (3-2)
Product Integration		Setting Right Customer Expectations (3-3)
Product Integration		Predictability (3-4)
Product Integration		Competitive Proposals (3-5)
Product Integration		Image (2-1)
Product Integration		Higher Customer Satisfaction (2-2)
Product Integration		Increased Revenues / Profits (1-1)
Process Area	**Expected Primary Benefits**	**Expected Secondary Benefits**
Verification	Better Quality Product (4-1)	Market Reach (3-1)
Verification	Better Risk Management (4-2)	Increased Productivity (3-2)
Verification		Setting Right Customer Expectations (3-3)
Verification		Predictability (3-4)
Verification		Competitive Proposals (3-5)
Verification		Image (2-1)
Verification		Higher Customer Satisfaction (2-2)
Verification		Increased Revenues / Profits (1-1)

Process Area	Expected Primary Benefits	Expected Secondary Benefits
Validation	Better Quality Product (4-1)	Market Reach (3-1)
Validation	Better Risk Management (4-2)	Increased Productivity (3-2)
Validation		Setting Right Customer Expectations (3-3)
Validation		Predictability (3-4)
Validation		Competitive Proposals (3-5)
Validation		Image (2-1)
Validation		Higher Customer Satisfaction (2-2)
Validation		Increased Revenues / Profits (1-1)
Process Area	**Expected Primary Benefits**	**Expected Secondary Benefits**
Risk Management	Better Quality Product (4-1)	Market Reach (3-1)
Risk Management	Better Risk Management (4-2)	Increased Productivity (3-2)
Risk Management		Setting Right Customer Expectations (3-3)
Risk Management		Predictability (3-4)
Risk Management		Competitive Proposals (3-5)
Risk Management		Image (2-1)
Risk Management		Higher Customer Satisfaction (2-2)
Risk Management		Increased Revenues / Profits (1-1)
Process Area	**Expected Primary Benefits**	**Expected Secondary Benefits**
Decision Analysis and Resolution	Better Quality Product (4-1)	Efficient Resource Management (4-3)
Decision Analysis and Resolution	Better Risk Management (4-2)	Market Reach (3-1)
Decision Analysis and Resolution	Understanding Customer Needs (4-4)	Increased Productivity (3-2)
Decision Analysis and Resolution		Setting Right Customer Expectations (3-3)
Decision Analysis and Resolution		Predictability (3-4)
Decision Analysis and Resolution		Competitive Proposals (3-5)
Decision Analysis and Resolution		Image (2-1)
Decision Analysis and Resolution		Higher Customer Satisfaction (2-2)
Decision Analysis and Resolution		Increased Revenues / Profits (1-1)

Level 4 Mapping

Process Area	Expected Primary Benefits	Expected Secondary Benefits
Organizational Process Performance	Improved Institutionalization of tools/process/methods (7-1)	Skill development facilitation by Management (6-1)
Organizational Process Performance	Business Focus (7-2)	Effective Information Management (6-2)
Organizational Process Performance	Market Intelligence (7-3)	Teaming / Synergize (6-3)
Organizational Process Performance		New Technology (6-4)
Organizational Process Performance		Retain & Develop Skills & Domain Knowledge (5-1)
Organizational Process Performance		Lower Time to Market (5-2)
Organizational Process Performance		Better Quality Product (4-1)
Organizational Process Performance		Better Risk Management (4-2)
Organizational Process Performance		Efficient Resource Management (4-3)
Organizational Process Performance		Understanding Customer Needs (4-4)
Organizational Process Performance		Market Reach (3-1)
Organizational Process Performance		Increased Productivity (3-2)
Organizational Process Performance		Setting Right Customer Expectations (3-3)
Organizational Process Performance		Predictability (3-4)
Organizational Process Performance		Competitive Proposals (3-5)
Organizational Process Performance		Image (2-1)
Organizational Process Performance		Higher Customer Satisfaction (2-2)
Organizational Process Performance		Increased Revenues / Profits (1-1)

Process Area	**Expected Primary Benefits**	**Expected Secondary Benefits**
Quantitative Project Management	Lower Time to Market (5-2)	Efficient Resource Management (4-3)
Quantitative Project Management	Better Quality Product (4-1)	Understanding Customer Needs (4-4)
Quantitative Project Management	Better Risk Management (4-2)	Market Reach (3-1)
Quantitative Project Management	Efficient Resource Management (4-3)	Increased Productivity (3-2)
Quantitative Project Management		Setting Right Customer Expectations (3-3)
Quantitative Project Management		Predictability (3-4)
Quantitative Project Management		Competitive Proposals (3-5)
Quantitative Project Management		Image (2-1)
Quantitative Project Management		Higher Customer Satisfaction (2-2)
Quantitative Project Management		Increased Revenues / Profits (1-1)

Level 5 Mapping

Process Area	Expected Primary Benefits	Expected Secondary Benefits
Organizational Innovation and Deployment	Improved Institutionalization of tools/process/methods (7-1)	Skill development facilitation by Management (6-1)
Organizational Innovation and Deployment	Business Focus (7-2)	Effective Information Management (6-2)
Organizational Innovation and Deployment	Market Intelligence (7-3)	Teaming / Synergize (6-3)
Organizational Innovation and Deployment		New Technology (6-4)
Organizational Innovation and Deployment		Retain & Develop Skills & Domain Knowledge (5-1)
Organizational Innovation and Deployment		Lower Time to Market (5-2)
Organizational Innovation and Deployment		Better Quality Product (4-1)
Organizational Innovation and Deployment		Better Risk Management (4-2)
Organizational Innovation and Deployment		Efficient Resource Management (4-3)
Organizational Innovation and Deployment		Understanding Customer Needs (4-4)
Organizational Innovation and Deployment		Market Reach (3-1)
Organizational Innovation and Deployment		Increased Productivity (3-2)
Organizational Innovation and Deployment		Setting Right Customer Expectations (3-3)
Organizational Innovation and Deployment		Predictability (3-4)
Organizational Innovation and Deployment		Competitive Proposals (3-5)
Organizational Innovation and Deployment		Image (2-1)
Organizational Innovation and Deployment		Higher Customer Satisfaction (2-2)
Organizational Innovation and Deployment		Increased Revenues / Profits (1-1)

Process Area	**Expected Primary Benefits**	**Expected Secondary Benefits**
Causal Analysis and Resolution	Improved Institutionalization of tools/process/methods (7-1)	Skill development facilitation by Management (6-1)
Causal Analysis and Resolution	Effective Information Management (6-2)	Teaming / Synergize (6-3)
Causal Analysis and Resolution	Lower Time to Market (5-2)	Retain & Develop Skills & Domain Knowledge (5-1)
Causal Analysis and Resolution	Better Quality Product (4-1)	Understanding Customer Needs (4-4)
Causal Analysis and Resolution	Better Risk Management (4-2)	Market Reach (3-1)
Causal Analysis and Resolution	Efficient Resource Management (4-3)	Increased Productivity (3-2)
Causal Analysis and Resolution		Setting Right Customer Expectations (3-3)
Causal Analysis and Resolution		Predictability (3-4)
Causal Analysis and Resolution		Competitive Proposals (3-5)
Causal Analysis and Resolution		Image (2-1)
Causal Analysis and Resolution		Higher Customer Satisfaction (2-2)
Causal Analysis and Resolution		Increased Revenues / Profits (1-1)

Appendix B (Final) Post-validation Level 2 Mapping

Summary of post-validation changes to RS-ICMMI mapping			
Process Area	Benefit Type	Action	Mapping
REQM	Primary	Addition	Predictability (3-4)
REQM	Secondary	Addition	Increased Productivity (3-2), Better Quality Product (4-1), Skill Development Facilitation by Management (7-3)
REQM	Secondary	Removal	Market Intelligence (7-3)
PMC	Secondary	Addition	Competitive Proposals (3-5)
SAM	Secondary	Addition	Efficient Resource Management (4-3), Efficient Information Management (6-2)
MA	Secondary	Addition	Improved Institutionalization of Process/Tools/Methods (7-1)
MA	Secondary	Removal	Market Reach (3-1)
PPQA	Secondary	Addition	Efficient Information Management (6-2), Teaming/Synergize (6-3), New Technology (6-4), Skill Development Facilitation by Management (7-3)
CM	Secondary	Addition	Competitive Proposals (3-5), Efficient Information Management (6-2)

Post-validation REQM benefits mapping	
Expected Primary Benefits	**Expected Secondary Benefits**
• Lower Time to Market (5-2) • Better Risk Management (4-2) • Understanding Customer Needs (4-4) • Predictability (3-4)	• Skill Development Facilitation by Management (6-1) • Retain & Develop Skills & Domain Knowledge (5-1) • Better Quality Product (4-1) • Efficient Resource Management (4-3) • Increased Productivity (3-2) • Predictability (3-4) • Competitive Proposals (3-5) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)

Post-validation PP benefits mapping	
Expected Primary Benefits	**Expected Secondary Benefits**
• Better Quality Product (4-1) • Better Risk Management (4-2) • Efficient Resource Management (4-3) • Understanding Customer Needs (4-4) • Setting Right Customer Expectations (3-3) • Predictability (3-4) • Competitive Proposals (3-5)	• Market Reach (3-1) • Increased Productivity (3-2) • Predictability (3-4) • Competitive Proposals (3-5) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)

Post-validation PMC benefits mapping	
Expected Primary Benefits	**Expected Secondary Benefits**
• Better Quality Product (4-1) • Better Risk Management (4-2) • Efficient Resource Management (4-3) • Setting Right Customer Expectations (3-3) • Predictability (3-4)	• Market Reach (3-1) • Increased Productivity (3-2) • Competitive Proposals (3-5) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)

Post-validation SAM benefits mapping	
Expected Primary Benefits	**Expected Secondary Benefits**
• Lower Time To Market (5-2) • Better Quality Product (4-1) • Better Risk Management (4-2) • Predictability (3-4)	• Efficient Information Management (6-2) • Retain & Develop Skills and Domain Knowledge (5-1) • Efficient Resource Management (4-3) • Market Reach (3-1) • Increased Productivity (3-2) • Setting Right Customer Expectations (3-3) • Predictability (3-4) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)

Post-validation MA benefits mapping	
Expected Primary Benefits	**Expected Secondary Benefits**
• Lower Time To Market (5-2) • Better Quality Product (4-1) • Better Risk Management (4-2) • Predictability (3-4)	• Improved Institutionalization of Tools/Process/Methods (7-1) • Skill Development Facilitation by Management (6-1) • Efficient Information Management (6-2) • Retain & Develop Skills & Domain Knowledge (5-1) • Increased Productivity (3-2) • Setting Right Customer Expectations (3-3) • Predictability (3-4) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)

Post-validation PPQA benefits mapping	
Expected Primary Benefits	**Expected Secondary Benefits**
• Improved Institutionalization of tools/process/methods (7-1) • Lower Time To Market (5-2) • Better Quality Product (4-1) • Better Risk Management (4-2) • Predictability (3-4)	• Skill Development Facilitation by Management (6-1) • Effective Information Management (6-2) • Teaming/Synergize (6-3) • New Technology (6-4) • Retain & Develop Skills & Domain Knowledge (5-1) • Efficient Resource Management (4-3) • Understanding Customer Needs (4-4) • Market Reach (3-1) • Increased Productivity (3-2) • Setting Right Customer Expectations (3-3) • Predictability (3-4) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)

Post-validation CM benefits mapping	
Expected Primary Benefits	**Expected Secondary Benefits**
• Teaming/Synergize (6-3) • Better Quality Product (4-1) • Better Risk Management (4-2) •	• Efficient Information Management (6-2) • Retain & Develop Skills & Domain Knowledge (5-1) • Lower Time To Market (5-2) • Efficient Resource Management (4-3) • Understanding Customer Needs (4-4) • Market Reach (3-1) • Increased Productivity (3-2) • Setting Right Customer Expectations (3-3) • Predictability (3-4) • Competitive Proposals (3-5) • Image (2-1) • Higher Customer Satisfaction (2-2) • Increased Revenues/Profits (1-1)

Appendix C Rosetta Stone Methodology Expert Panel Biographies

Swaraj Bhattacharia

Swaraj Bhattacharia currently works for a leading Indian software consulting firm which he has requested not be named. He has over 11 years experience in the software industry, of which 7 have involved working directly in CMM/.CMMI. He is currently responsible for ensuring that staff within his company are following the agreed CMMI-based lifecycle framework and are compliant with CMMI. He has also worked on ISO9000 projects.

Al Chatmon

Al is currently employed in Northrop Grumman Electronics Systems and has over 20 years' experience in Software Process Improvement. Al has published several papers on the benefits in Software Process Improvement.

Gillian Corkery

Gillian Corkery has over 6 years experience in Fidelity Investments where she was involved in several CMM Level 2 projects and holds a B.Sc. in Computer Science from University College Cork and.

Aldo Dagnino

Aldo has over 9 years' experience in Software Process Improvement and works for ABB (US) where he is responsible for all US-based software improvement activities using CMMI. Aldo is also an Adjunct Professor of Computer Science at North Carolina State University. He holds a Ph.D. from the University of Waterloo in Canada in Systems Engineering.

Pete Dittmar

Pete Dittmar is currently employed at Northrop Grumman Electronics Systems and has over 10 years experience in software process improvement. His background is in project management and finance.

Michael Doyle

Michael has 15 years' work experience in various companies including Ericsson Telecoms GSM & 3G divisions and Motorola (Ireland). Both companies are CMM Level 2 and Level 5 respectively and Michael has managed projects within the divisions that are CMM Level 2 and 5 compliant. Michael Doyle holds a B.Eng. in Electronic Engineering from the University of Limerick and an M.B.A. from the Smurfit Business School, University College Dublin.

Abina Falvey

Abina has been a project manager in Ericcson for over 9 years as well as having over 5 years' exposure to CMMI. She was involved in a project to adapt CMMI for Open Systems. Abina is the holder of a Computer Science (Honours) degree from University College Cork and a diploma in Project Management from the Smurfit Business School in University College Dublin.

Bob Fantina

Bob has over 10 years' experience in various companies including Research In Motion (RIM), MetLife, Merrill Lynch, Motorola, and Lucent Technologies. While in Lucent, he was responsible for preparing his division's compliance with CMM Level 2. Bob holds an M.Sc. in Administration Policy and Planning from Rutgers University and has written a book on SPI entitled "Practical Software Process Improvement."

Steve Fried

Steve currently works for Boeing Aerospace and has over 25 years experience in software development and project management for various Fortune 500 companies. He has over 12 years' process-related experience and was a core team member of the team which brought the Motorola (Cellphone) division to CMM Level 5.

Israel Gatt

Israel Gatt has 25 years' experience in IT, the last 7 of which have been in a company that specializes in CMMI-based Process Definition and Performance and Configuration Management.

Pat Lucey

Pat has over 17 years experience in Motorola (Ireland) where he has variously worked in software development, customer support, technical assistance, QA, and Process Management. He is currently the Managing Director of Aspiracon, a consulting and software development business based in Cork which specializes in Project and Process management. Pat holds a B.Eng. in Electronic Engineering from the University of Limerick.

Harvey Millner

Harvey Millner currently works for Satyam, an Indian IT consulting firm. He has over 16 years' experience in the IT industry and in 2005, while working for J.P. Morgan, was trained as a CMMI Assessment team member and participated on internal assessments for 3 years.

Amit Mitra

Amit Mitra has been working in the industry since 1974. During that time, he has worked in several large companies including the American Insurance Group (AIG) where he was the Chief Methodologist and Nynex/Verizon where he was the Director of Architecture. He currently teaches at the University of Arizona and University of California, San Diego (UCSD) and has published several books on Agile methodologies. Amit holds a B.Tech. from the Indian Institute of Technology and

Tom O'Kane

Tom is currently a lecturer in Computer Science in University College Cork. Before that Tom spent 12 years in industry working for Motorola (Ireland) and Motorola Labs (US). He is a qualified CMM Lead Assessor and, during his time in Motorola, he has lead 15 assessments and performed 16 supplier assessments. In addition, he also taught introductory and intermediate training on CMMI to staff and was the chair of the Motorola Lead Assessor program. Tom holds a B.Eng. in Computing, an M.Sc. in Information Systems and a Ph.D. on the topic of the Alignment of Business Strategy and Process Improvement.

Joan Rayford

Joan Rayford works for Innovision Technologies, a consulting firm which consults in software systems, particularly in system quality, software process improvement and the cost of failure. She has been working in the Industry since 1990, starting off as a software developer. She currently works on software process improvement consulting, particularly CMMI, and has American Society for Quality (ASQ) and International Association for Contract and Commercial Management (IACCM) certifications. She was also involved in bringing General Motors software division from a Level 1 through to Level 3.

April Reeve

April Reeve has over 28 years' experience in IT and 20 years' experience as a project manager. During that time, she has worked at several Financial Services organizations, including the CitiBank Global Securities processing organization where she worked for 11 years and was instrumental in bringing it from a CMM Level 1 to a Level 3 organization.

Rolf Reitzig

Rolf Reitzig is the owner of Cogence, an independent consulting firm which is a business partner to the SEI and which specializes in the Rational Unified Process (RUP) and CMMI implementation consulting. Cognence has been in existence for the last 10 years. Before that, Rolf has worked in the industry since 1990 and holds a B.Eng. in Computer Science Engineering from the University of Colorado and an M.B.A., also from the University of Colorada.

Appendix D RS-ICMMI Expert Panel Biographies

Colum Horgan

Colum has over 17 years industry experience in a variety of areas, primarily in QA and SPI. He started working in 1993 as a quality engineer and has consistently worked on ISO 9001 and CMM/CMMI SPI programs since. He joined Motorola (Cork) in 1998 and eventually was in charge of approximately 100 quality engineers there. He is currently a partner in Aspiracon, a company which specializes project management and business process management. In addition, he is currently the vice president of the Irish chapter of the Project Management Institute. Colum holds a B.Eng. in Electronic Engineering.

Charlie Penders

Charlie has been in the financial services industry for over 15 years. His exposure to SPI started in Morgan Stanley 15 years ago when they partnered with the Software Engineering Institute. In the intervening years he has continued his experience in CMM/CMMI and Six Sigma. Charlie holds one bachelor's degree in Telecommunications and another in Biology.

Fergal McCaffery

Fergal has worked in industry as both a software designer and senior manager in Nortel. In all, Fergal has over 7 years experience in practice and further 10 years in academia. Fergal holds a B.Sc. and a PhD in Computer Science from the University of Ulster.

Fran O'Hara

Fran is Principal Process Consultant and Practice Manager in Sogeti. He was a co-founder of Insight Test Services (since 2003) and founder and Principal Consultant of Insight Consulting (since 1996). Fran has worked in the software industry for over 25 years in research, safety-critical software development and in process improvement/quality assurance services across a range of sectors. He is a fellow of the ICS and a trained CMM lead assessor and TickIT auditor. He co-founded and is ex-chairman of the Irish Software Testing SIG, SoftTest Ireland (www.softtest.ie), a TMMi Foundation trustee and a regular presenter at international test and process improvement. Fran holds B.E. and M.Sc. degrees in Electronic Engineering.

Marty Sanders

Marty has over 50 years of experience in software, including development, maintenance, management and consulting of which over 20 year's experience has been in SPI. She holds a bachelor's degree in Ocean Engeering and a PhD in Computer Science from the University of Limerick.

Michael Doyle

Michael has 15 years' work experience in various companies including Ericsson Telecoms GSM & 3G divisions and Motorola (Ireland). Both companies are CMM Level 2 and Level 5 respectively and Michael has managed projects within the divisions that are CMM Level 2 and 5 compliant. Michael Doyle holds a B.Eng. in Electronic Engineering from the University of Limerick and an M.B.A. from the Smurfit Business School, University College Dublin.

Pat Lucey

Pat has over 17 years experience in Motorola (Ireland) where he has variously worked in software development, customer support, technical assistance, QA, and Process Management. He is currently the Managing Director of Aspiracon, a consulting and software development business based in Cork which specializes in Project and Process management. Pat holds a B.Eng. in Electronic Engineering from the University of Limerick.

John Burton

John is currently the Chief Technical Officer for Vitalograph and has worked in industry since 1997. John is also a co-author of a book on software risk management in the medical devices industry (Burton et al. 2009). John holds a B.Sc. in Computer Systems as well as a PhD in Computer Science, both from the University of Limerick.

Tom O'Kane

Tom is currently a lecturer in Computer Science in University College Cork. Before that Tom spent 12 years in industry working for Motorola (Ireland) and Motorola Labs (US). He is a qualified CMM Lead Assessor and, during his time in Motorola, he has lead 15 assessments and performed 16 supplier assessments. In addition, he also taught introductory and intermediate training on CMMI to staff and was the chair of the Motorola Lead Assessor program. Tom holds a B.Eng. in Computing, an M.Sc. in Information Systems and a Ph.D. on the topic of the Alignment of Business Strategy and Process Improvement.

Val Casey

Val has 25 years of software experience, of which 15 years is in SPI. Val holds a B.Sc. in Economics & Management from the University of London, an M.Sc. in Software Re-engineering from the University of Limerick and a PhD in Computer Science from the University of Limerick. His PhD is based on the implementation of global software development.

Appendix E Summary of CMMI Process Area to IGSI-ISM Benefits Map

Level	Process Area	Expected Primary Benefits	Expected Secondary Benefits	Total Non-Primary
2	Requirements Management	3	8	18
2	Project Management	7	7	14
2	Project Monitoring and Control	5	5	16
2	Supplier Agreement Management	4	8	17
2	Measurement & Analysis	4	7	17
2	Process and Product Quality Assurance	5	13	16
2	Configuration Management	3	11	18
Total Level 2		31	59	116

Level	Process Area	Expected Primary Benefits	Expected Secondary Benefits	Total Non-Primary
3	Requirements Development	4	9	17
3	Organizational Process Focus	3	18	18
3	Organizational Process Definition	2	16	19
3	Organizational Training	2	14	19
3	Technical Solution	4	8	17
3	Integrated Project Management for IPPD	5	10	16
3	Integrated Teaming	6	10	15
3	Integrated Supplier Management	8	10	13
3	Organizational Environment for Integration	5	16	16
3	Product Integration	2	8	19
3	Verification	2	8	19
3	Validation	2	8	19
3	Risk Management	2	8	19
3	Decision Analysis and Resolution	3	9	18
Total Level 3		50	152	244

Level	Process Area	Expected Primary Benefits	Expected Secondary Benefits	Total Non-Primary
4	Organizational Process Performance	3	18	18
5	Quantitative Project Management	4	10	17
Total Level 4		7	28	35
5	Organizational Innovation and Deployment	3	18	18
5	Causal Analysis and Resolution	6	12	15
Total Level 5		9	30	33
Total All Levels		97	269	428

Appendix F Expert Panel Interview Presentation

Rosetta Stone ROI Model

FIONBARR MCLOUGHLIN
ITA RICHARDSON
UNIVERSITY OF LIMERICK, IRELAND

Sunday, 16 August 2009

Contents

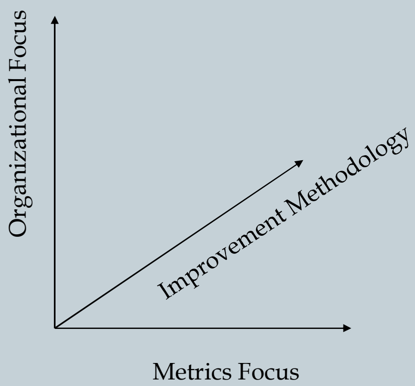
Funding provided by B4-Step/Science

Where are we currently?

- A lot of studies available on benefits of CMM/CMMI
- Many benefits are high-level benefits e.g. increased productivity, increased ROI
  - What do they mean? Where do they come from?
  - How are benefits related to each other?
  - How do they translate to concrete benefits?
- Smaller companies tend to want to focus on specific benefits
- Companies already have some metrics available to them – can they re-use them?

Funding provided by B4-Step/Science

Where are we currently (cont.)



Many valuable studies of the benefits resulting from implementation of CMM/CMMI and Software Process Improvement (SPI) in general have been undertaken over the last several years. These studies may be viewed as having at least separate three axes

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Why use the Rosetta Stone ROI (RSROI) Model?

- Provides a flexible framework that can be modified if needed
- Hierarchy of Business Objectives or Benefits – how one benefit can impact others
- Benefits fine-grained
- Allows re-use of metrics where appropriate
- Allows targeting of specific benefits

Funding provided by B4-Step/Science

The Rosetta Stone

- Wiki - http://en.wikipedia.org/wiki/Rosetta_Stone
- The **Rosetta Stone** is an ancient stele inscribed with the same passage of writing in two Egyptian language scripts and in classical Greek. It was created in 196 BC, discovered by the French in 1799, and translated in 1822. Comparative translation of the stone assisted in understanding many previously undecipherable examples of hieroglyphic writing.

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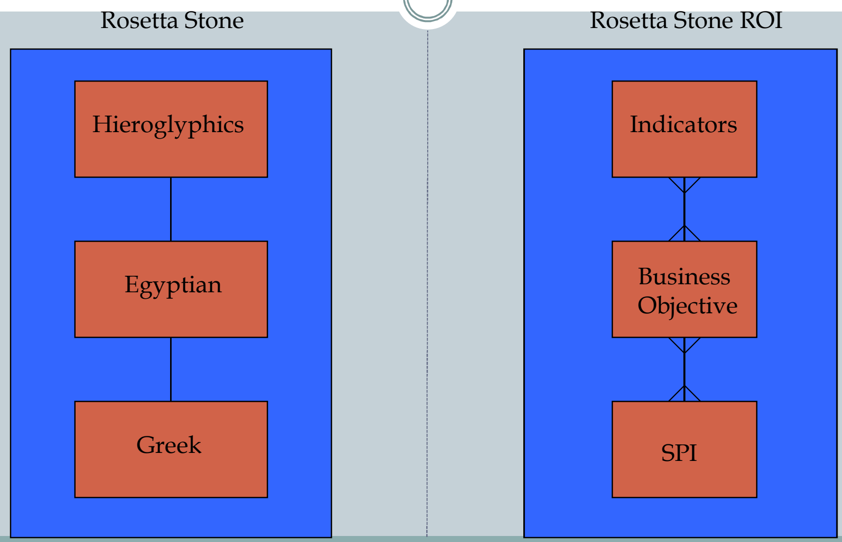
Rosetta Stone and the Rosetta Stone ROI Model



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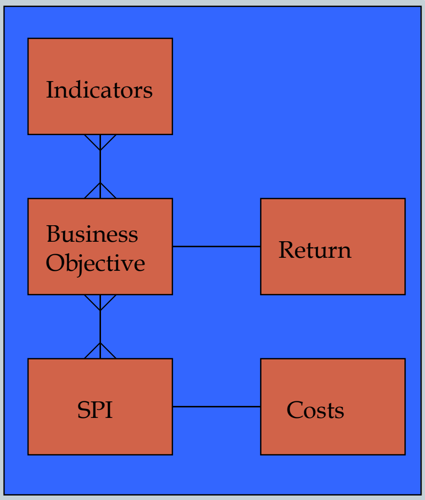
What is the Rosetta Stone ROI Model?



- a well-defined and extensible hierarchical set of Business Objectives associated with Software Process Improvement in general and CMMI in particular
- a mapping of those benefits by CMMI Process Areas
- an extensible set of performance measures and indicators. Users of the model are free to add any pre-existing, custom, or about-to-be-initiated performance measures that they may have, thus allowing them to re-use any existing work they have already undertaken or are about to undertake

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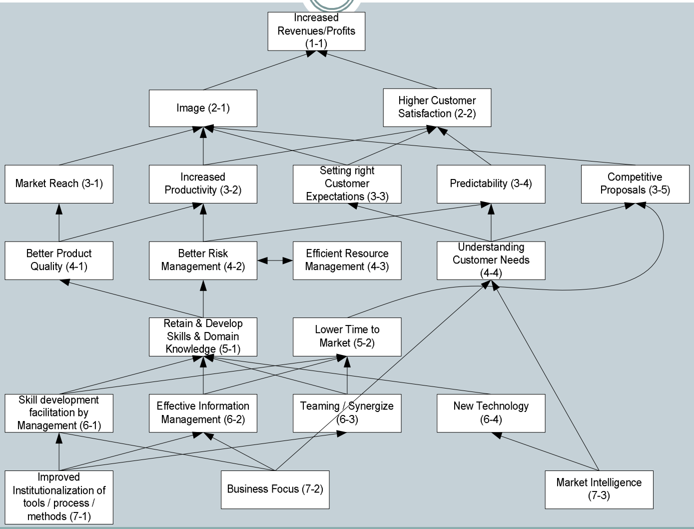
Benefits/Objectives

- Goyal et al. [1], as part of research undertaken on the benefits of SPI for IBM Global Services, India (IGSI), held two workshops that used consensus-based responses as inputs for an Interpretive Structural Modeling (ISM) methodology to develop a model of the needs and consequences of SPI
- This model is called the IGSI-ISM ROI Model and shows the relationships between the various benefits that can be derived from SPI. Using this model, there are 21 separate identifiable benefit areas.

Funding provided by B4-Step/Science

IGSI-ISM Benefit/Business Objectives Model



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Benefit Types

- Primary
  - Brought about as a direct result of implementation of a PA/SPI where the cause and effect relationship between the Process Area implementation and the benefit is very strong
- Derived
  - IGSI-ISM model is a hierarchical graph. Benefits elements that are closer to the root of the tree automatically accrue from benefits that are farther down if there is a path/relationship between them – these are *derived*

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Indicators/Metrics and SPI

- Indicators/Metrics
  - Metrics or indicators that will allow us to measure increased (or decreased) success in achieving benefits. In effect, these metrics act as proxies for the general benefit area
- SPI
  - Applicable to any SPI. For the purposes of this presentation we are interested in CMMI

Funding provided by B4-Step/Science

Costs, Return & ROI

- Benefits should ultimately lead to a monetary impact on the organization
- Some benefit impact may be difficult to quantify – how much does increased morale save an organization?
- SPI costs effort/money

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ROI

- ROI is typically some ratio of benefit to cost
- There are several popular methods for evaluating projects [2-4]:
  - Net Present Value (NPV)
  - Internal Rate of Return (IRR)
  - Return on Investment (ROI)
  - Profitability Index (PI)

Funding provided by B4-Step/Science

How RSROI Applies to CMMI – Level 2 Staged

- Requirements Management
  - Benefits - Better Risk Management, Understanding customer needs, Lower time to market
- Project Planning
  - Benefits – Better quality product, Better risk management, Efficient resource management, Understanding customer needs, Setting right customer expectations, predictability, Competitive proposals

Funding provided by B4-Step/Science Foundation of Ireland (SFI)

How RSROI Applies to CMMI – Level 2 Staged (cont.)

- Project Monitoring & Control
  - Benefits - *Better quality product, Better risk management, Efficient resource management, Setting right customer expectations, Predictability*
- Supplier Agreement Management
  - Benefits - *Better quality product, Better risk Management, predictability, Lower time to market*
- *Measurement & Analysis*
  - *Benefits - Better quality product, Better risk Management, predictability, Lower time to market*

Funding provided by B4-Step/Science Foundation of Ireland (SFI)

How RSROI Applies to CMMI – Level 2 Staged (cont.)

- Process and Product Quality Assurance
  - Benefits - *Improved institutionalization of Tools / Process / Methods, Better quality product, Better risk Management, predictability, Lower time to market*
- **Configuration Management**
  - Benefits - *Better quality product, Better risk management, Teaming / Synergize*

Funding provided by B4-Step/Science Foundation of Ireland (SFI)

CMMI Level 2 to Benefit Map

PA Identifier	Staged Level	Process Area	Expected Primary IGSI ROI Benefits	Expected Derived IGSI ROI Benefits
2-1	2 - Managed	Requirements Management	4-2, 4-4, 5-2	5-1, 2-1, 4-3, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
2-2		Project Planning	4-1, 4-2, 3-4, 3-5, 3-3, 4-3, 4-4	3-2, 3-4, 2-2, 1-1, 3-1, 3-3, 3-5, 2-1, 1-1
2-3		Project Monitoring and Control	4-2, 4-1, 4-3, 3-4, 3-3	3-1, 3-2, 3-3, 3-4, 2-1, 2-2, 1-1
2-4		Supplier Agreement Management	4-2, 4-1, 3-4, 5-2	3-1, 3-2, 3-3, 3-4, 2-1, 2-2, 1-1
2-5		Measurement and Analysis	4-2, 4-1, 5-2, 3-4	3-1, 3-2, 3-3, 3-4, 2-1, 2-2, 1-1
2-6		Process and Product Quality Assurance	4-1, 4-2, 5-2, 7-1, 3-4	6-1, 6-2, 6-3, 5-1, 5-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
2-7		Configuration Management	6-3, 4-2, 4-1	5-1, 5-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1

Funding provided by B4-Step/Science Foundation of

Meeting the Business Objectives of an Organization

- Approach/Process
  - Identify specific benefit you want to achieve/improve
  - Determine potential benefits for each PA
  - Determine relevant PAs
  - Identify indicators/metrics that can be used as proxies for benefits
  - Order implementations of PAs
  - Implement!
- Example - Lower Time to Market (5-2)

Funding provided by B4-Step/Science

Lower Time to Market

- Lower Time to Market (5-2) depends on:

IGSI-ISM Id	Objective Name
6-1	Skill development Facilitation by Management
6-2	Effective Information Management
6-3	Teaming/Synergize
7-1	Improved Institutionalization of Tools/Process/Methods
7-2	Business Focus

Funding provided by B4-Step/Science Foundation of

What Process Areas are linked to Business Objectives?

PA Identifier	Staged Level	Process Area	Expected Primary IGSI ROI Benefits	Expected Secondary IGSI ROI Benefits
2-1	2 - Managed	Requirements Management	4-2, 4-4, 5-2	5-1, 2-1, 4-3, 7-3, 3-4, 3-5, 2-1, 2-2, 1-1
2-4		Supplier Agreement Management	4-2, 4-1, 3-4, 5-2	3-1, 3-2, 3-3, 3-4, 2-1, 2-2, 1-1
2-5		Measurement and Analysis	4-2, 4-1, 5-2, 3-4	3-1, 3-2, 3-3, 3-4, 2-1, 2-2, 1-1
2-6		Process and Product Quality Assurance	4-1, 4-2, 5-2, 7-1, 3-4	6-1, 6-2, 6-3, 5-1, 5-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
2-7		Configuration Management	6-3, 4-2, 4-1	5-1, 5-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
3-1	3 - Defined	Requirements Development	5-2, 4-4, 4-2, 4-1	4-3, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
3-6		Organizational Process Focus	7-1, 7-2, 7-3	6-1, 6-2, 6-3, 6-4, 5-1, 5-2, 4-1, 4-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
3-7		Organizational Process Definition	6-2, 7-1	6-1, 6-3, 5-1, 5-2, 4-1, 4-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
3-8		Organizational Training	6-1, 6-3	5-1, 5-2, 4-1, 4-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
		Integrated Project Management	6-3, 4-1, 4-2, 4-3, 4-4	5-1, 5-2, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
3-9		Integrated Project Management for IPPD	6-3, 4-1, 4-2, 4-3, 4-4	5-1, 5-2, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
3-11		Integrated Teaming	6-3, 4-1, 4-3, 4-2, 4-4, 6-2	5-1, 5-2, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
3-12		Integrated Supplier Management	7-3, 6-3, 6-4, 4-1, 4-2, 7-2, 3-4, 5-2	5-1, 5-2, 4-3, 3-1, 3-2, 3-3, 3-5, 2-1, 2-2, 1-1
3-14		Organizational Environment for Integration	6-2, 6-3, 7-2, 5-2, 7-1	6-1, 6-2, 6-4, 5-1, 5-2, 4-1, 4-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
4-1	4 - Quantitatively Managed	Organizational Process Performance	7-1, 7-2, 7-3, 6-2	6-1, 6-3, 5-1, 5-2, 4-1, 4-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
4-2		Quantitative Project Management	4-1, 4-2, 4-3, 5-2	4-3, 4-4, 2-1, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
5-1	5 - Optimizing	Organizational Innovation and Deployment	7-1, 7-2, 7-3	6-1, 6-2, 6-3, 6-4, 5-1, 5-2, 4-1, 4-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
5-2		Causal Analysis and Resolution	6-2, 5-2, 4-1, 4-2, 4-3, 7-1	6-1, 6-3, 5-1, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 3, 1-1

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Prioritization of Implementation

- Factors:
  - More consideration should be given to those PAs that **primarily** satisfy a particular objective. By this we mean that those PAs that satisfy an objective as a primary objective should be given higher ranking than those that do not.
  - More consideration should be given to those PAs that, in the Staged Model, are **lower** in the Stage phases.

Funding provided by B4-Step/Science

A Recommended Order of Implementation

PA Identifier	Process Area	Expected Primary IGSI ROI Benefits
2-1	Requirements Management	4-2, 4-4, 5-2
2-4	Supplier Agreement Management	4-2, 4-1, 3-4, 5-2
2-5	Measurement and Analysis	4-2, 4-1, 5-2, 3-4
2-6	Process and Product Quality Assurance	4-1, 4-2, 5-2, 7-1, 3-4
3-1	Requirements Development	5-2, 4-4, 4-2, 4-1
3-12	Integrated Supplier Management	7-3, 6-3, 6-4, 4-1, 4-2, 7-2, 3-4, 5-2
3-14	Organizational Environment for Integration	6-2, 6-3, 7-2, 5-2, 7-1
4-2	Quantitative Project Management	4-1, 4-2, 4-3, 5-2
5-2	Causal Analysis and Resolution	6-2, 5-2, 4-1, 4-2, 4-3, 7-1
2-7	Configuration Management	6-3, 4-2, 4-1
3-6	Organizational Process Focus	7-1, 7-2, 7-3
3-7	Organizational Process Definition	6-2, 7-1
3-8	Organizational Training	6-1, 6-3
3-9	Integrated Project Management for IPPD	6-3, 4-1, 4-2, 4-3, 4-4
3-11	Integrated Teaming	6-3, 4-1, 4-3, 4-2, 4-4, 6-2
4-1	Organizational Process Performance	7-1, 7-2, 7-3, 6-2
5-1	Organizational Innovation and Deployment	7-1, 7-2, 7-3

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References

- [1] A. Goyal, S. Kanungo, V. Muthu, and S. Jayadevan, "ROI for SPI: Lessons from Initiatives at IBM Global Services India," presented at SEPG 2001, 2001.
- [2] E. F. Brigham and L. C. Gapenski, *Financial Management - Theory and Practice*: Dryden Press, 1994.
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- [4] S. A. Ross, R. W. Westerfield, and J. Jaffe, *Corporate Finance*, 5th Ed. ed: Irwin/McGraw-Hill, 1999.

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Questions?

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Appendix G Presentation to NDIA Conference 2006

The following presentation was delivered to the National Defense Industry Association Conference held in Denver, Colorado in June, 2006.

B4 - STEP
Building a Bi-directional Bridge Between Software ThEory and Practice

Rosetta Stone ROI Model

Fionbarr McLoughlin
Ita Richardson
University of Limerick, Ireland

Wednesday, 02 June 2010

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Contents

B4 - STEP
Building a Bi-directional Bridge Between Software ThEory and Practice

- Current state of play
- Rosetta Stone Model – Introductory concepts
- IGSI-ISM Benefits/Objectives Model
- CMMI Level 2 (Staged) Benefit mapping
- How to achieve specific Benefits

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Where are we currently?

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- A lot of studies available on benefits of CMM/CMMI
- Many benefits are high-level benefits e.g. increased productivity, increased ROI
  - What do they mean? Where do they come from?
  - How are benefits related to each other?
  - How do they translate to concrete benefits?
- Smaller companies tend to want to focus on specific benefits
- Companies already have some metrics available to them – can they re-use them?

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Why use the Rosetta Stone ROI (RSROI) Model?

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- Provides a flexible framework that can be modified if needed
- Hierarchy of Business Objectives or Benefits – how one benefit can impact others
- Benefits fine-grained
- Allows re-use of metrics where appropriate
- Allows targeting of specific benefits

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The Rosetta Stone

- Wiki - http://en.wikipedia.org/wiki/Rosetta_Stone
- The **Rosetta Stone** is an ancient stele inscribed with the same passage of writing in two Egyptian language scripts and in classical Greek. It was created in 196 BC, discovered by the French in 1799, and translated in 1822. Comparative translation of the stone assisted in understanding many previously undecipherable examples of hieroglyphic writing.

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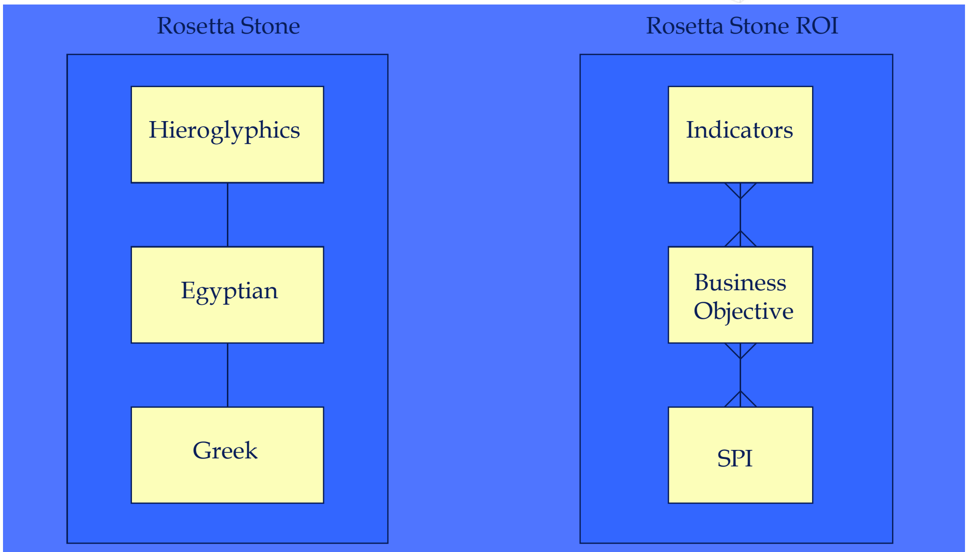
Rosetta Stone and the Rosetta Stone ROI Model



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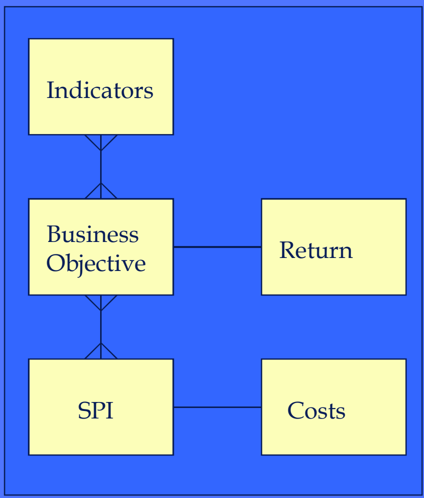
What is the Rosetta Stone ROI Model?



- a well-defined and extensible hierarchical set of Business Objectives associated with Software Process Improvement in general and CMMI in particular
- a mapping of those benefits by CMMI Process Areas
- an extensible set of performance measures and indicators. Users of the model are free to add any pre-existing, custom, or about-to-be-initiated performance measures that they may have, thus allowing them to re-use any existing work they have already undertaken or are about to undertake

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Benefits/Objectives

- Goyal et al. [1], as part of research undertaken on the benefits of SPI for IBM Global Services, India (IGSI), held two workshops that used consensus-based responses as inputs for an Interpretive Structural Modeling (ISM) methodology to develop a model of the needs and consequences of SPI
- This model is called the IGSI-ISM ROI Model and shows the relationships between the various benefits that can be derived from SPI. Using this model, there are 21 separate identifiable benefit areas.

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IGSI-ISM Benefit/Business Objectives Model

- STEP
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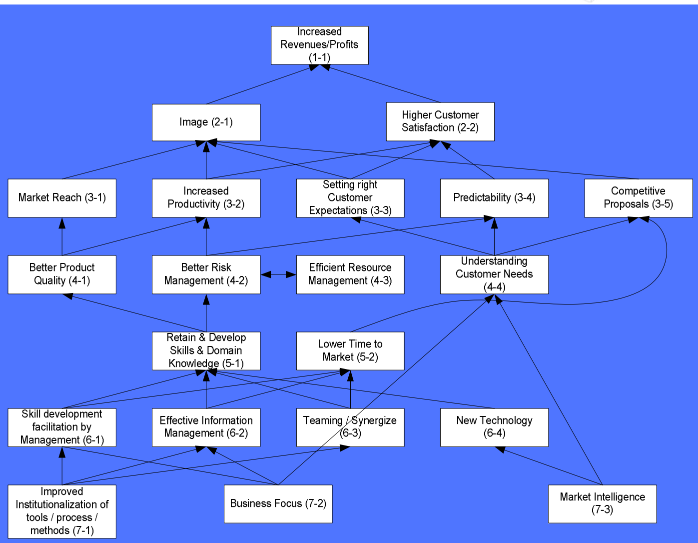

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Benefit Types

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- Primary
  - Brought about as a direct result of implementation of a PA/SPI where the cause and effect relationship between the Process Area implementation and the benefit is very strong
- Derived
  - IGSI-ISM model is a hierarchical graph. Benefits elements that are closer to the root of the tree automatically accrue from benefits that are farther down if there is a path/relationship between them – these are <u>*derived*</u>

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Indicators/Metrics and SPI

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- Indicators/Metrics
  - Metrics or indicators that will allow us to measure increased (or decreased) success in achieving benefits. In effect, these metrics act as proxies for the general benefit area
- SPI
  - Applicable to any SPI. For the purposes of this presentation we are interested in CMMI

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Costs, Return & ROI

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- Benefits should ultimately lead to a monetary impact on the organization
- Some benefit impact may be difficult to quantify – how much does increased morale save an organization?
- SPI costs effort/money

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ROI

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- ROI is typically some ratio of benefit to cost
- There are several popular methods for evaluating projects [2-4]:
  - Net Present Value (NPV)
  - Internal Rate of Return (IRR)
  - Return on Investment (ROI)
  - Profitability Index (PI)

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How RSROI Applies to CMMI – Level 2 Staged

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- Requirements Management
  - Benefits - Better Risk Management, Understanding customer needs, Lower time to market
- Project Planning
  - Benefits – Better quality product, Better risk management, Efficient resource management, Understanding customer needs, Setting right customer expectations, predictability, Competitive proposals

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How RSROI Applies to CMMI – Level 2 Staged (cont.)

B4 - STEP
Building a Bi-directional Bridge Between Software ThEory and Practice

- Project Monitoring & Control
  - Benefits - *Better quality product, Better risk management, Efficient resource management, Setting right customer expectations, Predictability*
- Supplier Agreement Management
  - Benefits - *Better quality product, Better risk Management, predictability, Lower time to market*
- *Measurement & Analysis*
  - *Benefits - Better quality product, Better risk Management, predictability, Lower time to market*

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How RSROI Applies to CMMI – Level 2 Staged (cont.)

B4 - STEP
Building a Bi-directional Bridge Between Software ThEory and Practice

- Process and Product Quality Assurance
  - Benefits - *Improved institutionalization of Tools / Process / Methods, Better quality product, Better risk Management, predictability, Lower time to market*
- **Configuration Management**
  - Benefits - *Better quality product, Better risk management, Teaming / Synergize*

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CMMI Level 2 to Benefit Map

PA Identifier	Staged Level	Process Area	Expected Primary IGSI ROI Benefits	Expected Derived IGSI ROI Benefits
2-1	2 - Managed	Requirements Management	4-2, 4-4, 5-2	5-1, 2-1, 4-3, 7-3, 3-4, 3-5, 2-1, 2-2, 1-1
2-2		Project Planning	4-1, 4-2, 3-4, 3-5, 3-3, 4-3, 4-4	3-2, 3-4, 2-2, 1-1, 3-1, 3-3, 3-5, 2-1, 1-1
2-3		Project Monitoring and Control	4-2, 4-1, 4-3, 3-4, 3-3	3-1, 3-2, 3-3, 3-4, 2-1, 2-2, 1-1
2-4		Supplier Agreement Management	4-2, 4-1, 3-4, 5-2	3-1, 3-2, 3-3, 3-4, 2-1, 2-2, 1-1
2-5		Measurement and Analysis	4-2, 4-1, 5-2, 3-4	3-1, 3-2, 3-3, 3-4, 2-1, 2-2, 1-1
2-6		Process and Product Quality Assurance	4-1, 4-2, 5-2, 7-1, 3-4	6-1, 6-2, 6-3, 5-1, 5-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
2-7		Configuration Management	6-3, 4-2, 4-1	5-1, 5-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1

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Meeting the Business Objectives of an Organization

- Approach/Process
  - Identify specific benefit you want to achieve/improve
  - Determine potential benefits for each PA
  - Determine relevant PAs
  - Identify indicators/metrics that can be used as proxies for benefits
  - Order implementations of PAs
  - Implement!
- Example - Lower Time to Market (5-2)

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Lower Time to Market

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- Lower Time to Market (5-2) depends on:

IGSI-ISM Id	Objective Name
6-1	Skill development Facilitation by Management
6-2	Effective Information Management
6-3	Teaming/Synergize
7-1	Improved Institutionalization of Tools/Process/Methods
7-2	Business Focus

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What Process Areas are linked to Business Objectives?

B4 - STEP
Building a Bi-directional Bridge Between Software ThEory and Practice

PA Identifier	Staged Level	Process Area	Expected Primary IGSI ROI Benefits	Expected Secondary IGSI ROI Benefits
2-1	2 - Managed	Requirements Management	4-2, 4-4, 5-2	5-1, 2-1, 4-3, 7-3, 3-4, 3-5, 2-1, 2-2, 1-1
2-4		Supplier Agreement Management	4-2, 4-1, 3-4, 5-2	3-1, 3-2, 3-3, 3-4, 2-1, 2-2, 1-1
2-5		Measurement and Analysis	4-2, 4-1, 5-2, 3-4	3-1, 3-2, 3-3, 3-4, 2-1, 2-2, 1-1
2-6		Process and Product Quality Assurance	4-1, 4-2, 5-2, 7-1, 3-4	6-1, 6-2, 6-3, 5-1, 5-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
2-7		Configuration Management	6-3, 4-2, 4-1	5-1, 5-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
3-1	3 - Defined	Requirements Development	5-2, 4-4, 4-2, 4-1	4-3, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
3-6		Organizational Process Focus	7-1, 7-2, 7-3	6-1, 6-2, 6-3, 6-4, 5-1, 5-2, 4-1, 4-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
3-7		Organizational Process Definition	6-2, 7-1	6-1, 6-3, 5-1, 5-2, 4-1, 4-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
3-8		Organizational Training	6-1, 6-3	5-1, 5-2, 4-1, 4-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
		Integrated Project Management	6-3, 4-1, 4-2, 4-3, 4-4	5-1, 5-2, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
3-9		Integrated Project Management for IPPD	6-3, 4-1, 4-2, 4-3, 4-4	5-1, 5-2, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
3-11		Integrated Teaming	6-3, 4-1, 4-3, 4-2, 4-4, 6-2	5-1, 5-2, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
3-12		Integrated Supplier Management	7-3, 6-3, 6-4, 4-1, 4-2, 7-2, 3-4, 5-2	5-1, 5-2, 4-3, 3-1, 3-2, 3-3, 3-5, 2-1, 2-2, 1-1
3-14		Organizational Environment for Integration	6-2, 6-3, 7-2, 5-2, 7-1	6-1, 6-2, 6-4, 5-1, 5-2, 4-1, 4-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
4-1	4 - Quantitatively Managed	Organizational Process Performance	7-1, 7-2, 7-3, 6-2	6-1, 6-3, 5-1, 5-2, 4-1, 4-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
4-2		Quantitative Project Management	4-1, 4-2, 4-3, 5-2	4-3, 4-4, 2-1, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
5-1	5 - Optimizing	Organizational Innovation and Deployment	7-1, 7-2, 7-3	6-1, 6-2, 6-3, 6-4, 5-1, 5-2, 4-1, 4-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
5-2		Causal Analysis and Resolution	6-2, 5-2, 4-1, 4-2, 4-3, 7-1	6-1, 6-3, 5-1, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 3, 1-1

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Prioritization of Implementation

B4 - STEP
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- Factors:
  - More consideration should be given to those PAs that **primarily** satisfy a particular objective. By this we mean that those PAs that satisfy an objective as a primary objective should be given higher ranking than those that do not.
  - More consideration should be given to those PAs that, in the Staged Model, are **lower** in the Stage phases.

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A Recommended Order of Implementation

B4 - STEP
Building a Bi-directional Bridge Between Software ThEory and Practice

PA Identifier	Process Area	Expected Primary IGSI ROI Benefits
2-1	Requirements Management	4-2, 4-4, 5-2
2-4	Supplier Agreement Management	4-2, 4-1, 3-4, 5-2
2-5	Measurement and Analysis	4-2, 4-1, 5-2, 3-4
2-6	Process and Product Quality Assurance	4-1, 4-2, 5-2, 7-1, 3-4
3-1	Requirements Development	5-2, 4-4, 4-2, 4-1
3-12	Integrated Supplier Management	7-3, 6-3, 6-4, 4-1, 4-2, 7-2, 3-4, 5-2
3-14	Organizational Environment for Integration	6-2, 6-3, 7-2, 5-2, 7-1
4-2	Quantitative Project Management	4-1, 4-2, 4-3, 5-2
5-2	Causal Analysis and Resolution	6-2, 5-2, 4-1, 4-2, 4-3, 7-1
2-7	Configuration Management	6-3, 4-2, 4-1
3-6	Organizational Process Focus	7-1, 7-2, 7-3
3-7	Organizational Process Definition	6-2, 7-1
3-8	Organizational Training	6-1, 6-3
3-9	Integrated Project Management for IPPD	6-3, 4-1, 4-2, 4-3, 4-4
3-11	Integrated Teaming	6-3, 4-1, 4-3, 4-2, 4-4, 6-2
4-1	Organizational Process Performance	7-1, 7-2, 7-3, 6-2
5-1	Organizational Innovation and Deployment	7-1, 7-2, 7-3

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References

- [1] A. Goyal, S. Kanungo, V. Muthu, and S. Jayadevan, "ROI for SPI: Lessons from Initiatives at IBM Global Services India," presented at SEPG 2001, 2001.
- [2] E. F. Brigham and L. C. Gapenski, *Financial Management - Theory and Practice*: Dryden Press, 1994.
- [3] R. C. Higgins, *Analysis for Financial Management*, vol. 5th: Irwin/McGraw-Hill, 1998.
- [4] S. A. Ross, R. W. Westerfield, and J. Jaffe, *Corporate Finance*, 5th Ed. ed: Irwin/McGraw-Hill, 1999.

Funding provided by B4-Step/Science Foundation of Ireland (SFI)

Appendix H PROFES2010 Conference Paper

The following paper was accepted for the PROFES2010 conference in the University of Limerick in June 2010.

The Rosetta Stone Methodology – A Benefits Driven Approach to Software Process Improvement

Fionbarr McLoughlin & Ita Richardson

Lero – the Irish Software Engineering Research Centre, University of Limerick, Limerick, Ireland

Abstract. In response to the lack of a business-focused approach to software process improvement (SPI), the Rosetta Stone objective-driven SPI Methodology (RSM) has been developed which allows organizations to undertake SPI based on business-driven objectives using proven SPI methodologies. To demonstrate usefulness and practicality, the Rosetta Stone IGSI-ISM to CMMI Instance mapping (RS-ICMMI) is developed using a generic set of business objectives which are mapped to the CMMI (Staged) model using a modified version of GQM. This methodology and the RS-ICMMI instance have been validated by experts.

1 Introduction

In companies, a significant amount of capital expenditure and operating expenses are spent on Information and Communications Technology (ICT). In fact, according to the Organization for Economic Co-Operation and Development (OECD) [1], total worldwide spending on ICT was expected to reach $2.964 trillion in 2005 (the most recent OECD estimates). Therefore, it is important that the ICT maturing process continues to evolve. From a Software Process Improvement (SPI) perspective, there are several competing and, in some cases, complementary standards such as the Software Engineering Institute's CMMI for Development version 1.2 [2]; the International Standards Organization's (ISO) ISO15504 [3], formerly known as SPICE; the Trillium Model [4], developed originally in 1991 by Bell Canada; the ISO's 9000-3 standard [5] and the ISO 9001:2000 standard [6], a process-driven approach to define, establish and maintain software quality within an organization that will allow organizations to meet their business objectives [7].

Quite a deal of literature supports the hypothesis that implementation of the various SPI methodologies will result in benefits to organizations. However, they do so from an IT perspective. There are few, if any, methodologies which approach systems improvement from a business goals and objectives perspective. Our research has demonstrated that these benefits come about *as a result* of implementation of SPI which is IT-centric. In other words, ICT drives the business benefits. The Rosetta

Stone Methodology[1], developed and evaluated as part of our research and presented in this paper, consists of a methodology which allows businesses to undertake business- and organizational-driven goals and objectives.

Section 2 of this paper describes the reported benefits of implementing software process improvement, and our research method is described in section 3. In section 4, we present the development of the Rosetta Stone Methodology, its constituent elements and a specific implementation. This is followed by a discussion and conclusion in sections 5 and 6.

2 Benefits of SPI

Software and systems development methodologies have evolved to enable the development of ever larger and more complex solutions to real-world problems. However, there are concerns and while advances have been made there are still quite a few horror stories reported [8]. To get to where we are now has resulted from the gradual evolution of development processes. This evolution includes, but is not limited to, solutions such as software inspections [9], structured programming [10], software process improvement techniques and project management methodologies. We are cognisant of the work of Solon and Statz [11] and Zahran [12] when they discuss the difficulties of using benchmark SPI benefits in making business cases for the implementation of SPI. While at a high level benefits are categorized consistently in macro terms such as Return On Investment (ROI), Quality, Defect Density, and Reduced Cycle Times, upon more detailed review results are not normalized nor is there consistency in how benefits are defined. An additional problem is that much of the literature deals with the results of SPI from individual organizations. Also, there are benefits which, while of interest to the community as a whole, are mentioned in only a small minority of research reports.

We now present an overview of the reported benefits resulting from the implementation of SPI. Our intention here is not to provide an exhaustive review of all the reported benefits of SPI but merely to demonstrate that there is considerable evidence to support the view that SPI is beneficial to organizations.

2.1 Reported Benefits of SPI

Return On Investment (ROI) reviews often feature large companies. Humphrey et al. [13] described the Software Process Improvement initiative at Hughes Aircraft where,

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[1] The Rosetta Stone is an Egyptian stele found by the French in 1799 with three translations of a single passage in Hieroglyphics, Demotic, and classical Greek. It allowed scholars to translate between these three languages. The analogy is that the Rosetta Stone Methodology will allow the translation between business objectives and SPI methodologies.

during a 4 year period (1987-1990) they progressed to CMM Level 3. From an ROI perspective, the assessments cost Hughes Aircraft $45,000 and a further $400,000 over the two-year program of improvements. Hughes estimated savings to be about $2 million. The effects of a CMM-based SPI program at Software Systems Laboratory (SSL) within Raytheon Inc. are described in [14], [15]. Over 5 years this program cost $5million, and the organisation progressed from Level 1 to Level 3, and was working towards a Level 4 assessment. ROI had increased by a factor of 7.7 based on a sample of six projects. Boeing STS, a division of Boeing Inc. that supports space transportation programs for the Department of Defense and NASA, achieved a rating of CMM Level 5 in July 1996. Yamamura and Wigle [16] present an analysis of cost-to-benefit ratios citing a reduction in rework effort by 31% due to formal inspection alone - this translated into a 7.7:1 ROI. In reporting on the progression of the Oklahoma City Air Logistics Center (OC-ALC) from CMM Level 1 to CMM Level 4, Butler and Lipke [17] reported that, for an investment of $6 million, the OC-ALC calculated a reduction in cost of $50.5 million – an 8.4:1 ROI. To further support the argument that ROI increases as a result of implementation of CMMI, the SEI [18] reported an increased ROI of between 2:1 and 27.7:1%, with a median increase in ROI of 4.7:1, based on 16 separate data points. In addition to the individual reports outlined above, both El Emam and Briand [19] and Krasner [20] report summary evidence of the benefits of SPI.

There are many studies which demonstrate that productivity increases as a result of software process improvement. Brodman and Johnson [21], [22], [23] investigated the effect of improving process capability in 33 companies who were at various levels of CMM maturity. They demonstrate increases in productivity ranging from 6.4% to 100%. A study of four projects was undertaken by Software Productivity Research Inc. of the benefits of SPI within Oklahoma City Air Logistics Center (OC-ALC) [24]. This determined that there was a 10 times increase in productivity from the baseline project to their most recent project (while OC-ALC was at CMM Level 2, working its way to Level 4). Dion [14], [15] also reported Productivity increases of a factor of 2.3 in a 5 year time period as a result of implementing CMM. Also reporting productivity increases as a result of implementation of CMM are Herbsleb et al.[25], [26]. Their report shows a productivity increase of between 9% and 67% over a wide range of maturity levels after implementing CMM, with the median increase being 35%.

Goldenson and Gibson [27] detail some preliminary results from the application of CMMI process improvement. In particular, they quoted a 30% increase in Productivity as a result of implementation of CMMI. In a follow-up to the initial 2003 report, the SEI [28] attributed productivity increases as a result of implementation of CMMI of between 9% and 255%, with a median value of 62%. Garmus and Iwanicki [29] report productivity increases of 132% (based on Function Point/Effort Month), and an effort reduction by 50%. NASA's (National Aeronautics and Space Administration) SEL (Software Engineering Laboratory) spent 10 years undertaking an SPI initiative at their Goddard Space Flight Center. Reporting on the SEL in 1994, Krasner, Pyles et al. [30] report that predicted costs were always within 10% of actual costs; only one deadline was missed in 10 years; maintenance cost of code was half that at other IBM software facilities; defects of 0.01 per thousand lines of source code

(KSLOC); and an increased error detection rate of 95%. Krasner [31] further reported a reduction in error rates of 75% between 1985 and 1993, a reduction of software development costs by 55%, and an increase of reuse by 300%. He also notes that costs have become more predictable. Yamamura and Wigle [16], in their report on their implementation of CMM Level 5, report that their processes were finding 89% of the defects – thus leaving 11% still baked in. After implementing SPI, virtually 100% of all defects are found. Putnam and Myers [32] reported that quality improvements (by defect ratio) fell from just over 0.1 defects per 1 KSLOC to 0 defects per KSLOC.

The SEI [18], based on 20 separate data points, has attributed quality increases of between 7 and 132%, with a median of 50% to the successful implementation of CMMI. From a defect perspective, McLoone and Rohde [33] found a significant reduction in the hours/KSLOC metric and another reduction in the dollars/KSLOC cost while Garmus and Iwanicki [29] report a reduction in defect density of 75%, all through CMMI implementation. Liu [34] reports significant improvements as a result of Motorola's implementation of CMMI Level 5 in their sites in China. Between 2003 and 2006, Cost of Quality was reduced from approximately 35% to 25%, fewer defects were inserted into code and the faults per line of code was reduced by 13.01% from its pre-CMMI Level 5 level. Studies analysed demonstrate that as organizations implement more quality-oriented processes, the quality of code improves. Additionally, quality increases as process capability maturity levels increase. We also note that it becomes more difficult, and therefore more costly, to increase quality between higher maturity levels.

There is a note of caution, however, associated with these reported results. While there appears to be clear evidence of a correlation between increased ROI and implementation of various SPI initiatives, there also seems to be a trade-off between ROI and Quality, which would seem natural. In the case of SPI programs like CMM and CMMI, the higher an organization progresses up the maturity ladder, the more quality processes are put in place and therefore there is a tendency for quality to increase but, at the same time, ROI decreases [35]. As Fayad and Laitinen [36] note, "moving to levels 4 and 5 sounds worthwhile but there is little empirical evidence to support the move." In addition, while there is consistent evidence of increases in productivity coinciding with the implementation of CMM/CMMI, there is also evidence to suggest that the rate of increase in productivity is not uniformly higher as successive CMM/CMMI levels are implemented. In addition, some research suggests that at least part of the productivity increases relates to technological innovation as a result of process improvement.

2.2 SPI Challenges

There are several challenges associated with the interpretation and use of the research we have reported in the previous sections. Firstly, there is a lack of uniformity in the definition and interpretation of the metrics/indicators used as evidence of the benefits of SPI. Different researchers and practitioners use the same metric to mean different things. Secondly, for various reasons, not all companies, even when using standard industry definitions for metrics, use the same metrics in their studies. The effect of this is that, while there may be quite a lot of research, it is sometimes difficult to find like-metrics upon which to base comparisons. Thirdly, companies may be reluctant to divulge information for commercial reasons, particularly if the results of their SPI effort paint them in a worse light than their peers. Therefore, it is difficult to find studies which report negatively on process improvements.

However, to say that SPI in itself is the silver bullet for the software development process would be less than disingenuous. Nothing in life is free and SPI is no exception to this rule. Various criticisms such as high cost, rigidity in approach, and the increased administrative overhead associated with SPI have all been levelled at SPI – or more particularly at SPI models such as CMMI or ISO15504 [37], [38]. These have been legitimate criticisms. However, it is up to individual organizations to balance the increased costs of assessment and accreditation, the increased size and overhead associated with the SPI model, and any issues arising from rigidity in application of the model with the benefits to the organization as a whole.

In summary, there is a lot of evidence in the literature to show that there are definite benefits to be realized from implementing SPI. However, we have noted little evidence to show that implementation of particular process improvements have a particular effect on the business requirement.

2.3 Bridging the Gap between SPI and the Business

As noted in section 1, there are several SPI methodologies currently available for organizations to use in order to improve their software processes. These methodologies are software centric and are often not tightly linked to an organization's business goals and objectives. In fact, Debou and Kuntzmann-Combelles [39] contend that the major bottleneck to the success of SPI initiatives is the lack of business orientation in how the program is run. Specifically with regard to CMMI, Liu et al. [40] state that there exists a disconnect between business goals and maturity levels. The RSM bridges these gaps by adding two weapons to the practitioner's arsenal. Firstly, it provides a generic methodology, based on a modified version of GQM [41], [42], which can be used to couple a generic benefits model to an arbitrary SPI. Secondly, and perhaps more importantly from a practitioner's perspective, it provides an implementation of the RSM using a for-profit benefits model tied to an industry-standard SPI methodology which has been validated by industry peers and modified based on their feedback.

3 Research Methodology

The research commenced with a literature review and initial interviews with academics and industry personnel. No approach was identified which supported businesses in deciding which software processes to improve to gain specific business benefits. Therefore, the purpose of our research is to create an objectives-driven approach whose use should allow this. It is expected to save organizations both time and resources by allowing them to focus only on those process areas which have a direct bearing on the business objectives they are trying to achieve.

The first step was to create a generic methodology, the Rosetta Stone Methodology (RSM). This was done by creating a meta-model of all the elements involved in an SPI implementation (see LHS of Fig. 1). After this, a step-by-step approach was developed which guides practitioners in using an SPI methodology and benefits model to define a mapping between business-focused benefits and individual SPI process areas. In essence, this process allows practitioners to substitute the meta-model with a concrete implementation instance of the model (see RHS of Fig. 1). This mapping is then used as the basis to answer various questions regarding which process areas should be implemented to achieve specific business benefits and in what particular order.

To demonstrate the implementation of the RSM in a specific instance, we investigated available return on investment models which did not deal exclusively with software process improvement, but with which existing SPI models could be combined. We chose to work with the IGSI-ISM Benefits Model [43] and CMMI Version 1.2 [2]. This is done as follows:

1. Determine which benefits model and which SPI model which is to be used;
2. Define the mapping (relationships) between objectives/benefits and software processes;
3. Answer the questions that are relevant to the individual organization.

The initial methodology, meta-model and implementation instance were developed as described and were then reviewed by a small group of peers for validity. For triangulation purposes, they were validated through a Delphi review of 17 people with an average work experience in the software industry of 19 years along with an average of 11 years of SPI experience. Additionally, to validate the implementation instance, a group of experts was interviewed about each relationship within the RS-ICMMI model. Out of a pool of ten experts, two experts were randomly selected to review a set of IGSI-ISM Benefit/CMMI Level 2 combinations. They discussed whether they agreed with the relationship presented and where they had seen these relationships work in practice. This process was repeated until all combinations had been reviewed. In some cases, the RS-ICMMI was modified as a result of these interviews.

4 Rosetta Stone Methodology

While there are many reported benefits from SPI projects, our observation is that the SPI agenda has been undertaken to improve particular processes for the process-sake, rather than organizational benefits as the primary objective. This is typically not the way the commercial world works. Therefore, to achieve a business-oriented focus, the outcome from our research will allow organizations to achieve organization-specific objectives through improving their software process.

In the first instance we have developed the Rosetta Stone Meta Model. The meta-model is, in essence, an entity-relationship model which relates together all the major elements within any SPI initiative – business objectives desired, returns associated with achieving the business benefits, process areas, costs of implementing the process areas, and the metrics/indicators to determine progress/regression towards the objectives (see LHS of Fig. 1). The Rosetta Stone Methodology (RSM) consists of using the Rosetta Stone Meta Model to create a concrete instance of the meta model. The main benefits of using this methodology are that users are able to:

- Achieve specific business objectives by targeting particular software processes to improve in order to achieve business benefits
- Understand what benefits may be derived from the improvement of which particular software process
- Given a set of existing metrics and values, determine what processes may be more readily and quickly implemented than others.

4.1 Objectives, Process Areas, and Indicators

The most important element in RSM is the *set of business objectives* or *benefits* which an organization wishes to achieve. If possible, these should be hierarchical so that the achievement of one should lead to the achievement of others. For example, if on-time delivery of projects is achieved (one possible business objective) then this should result in better customer satisfaction (another possible business objective). Each benefit should have some form of *return* associated with it – some way of determining, frequently quantifiable but sometimes qualitative, the value of the benefit. Returns are meaningful to the business and, as such, are typically not SPI-type metrics such as defects/KSLOC or defects/function point – unless, of course, the business is primarily focused on software development. For example, if productivity were the objective, it might be possible to say that, for an x% increase in productivity, there should be an increase in profits of y%. For each objective, there is at least one *indicator* - a set of metric(s) that are an indication that a particular benefit has occurred. In other words, a set of indicators that can prove (or disprove) that progress is being made towards a specific benefit – a way to measure a benefit. *Process areas* are those processes which are being improved during the SPI program, and would include, for example requirements management, risk management and project planning. Each process area has a *cost* associated with it – costs associated with implementing the improvement.

In order to make a concrete instance of the model, the practitioner must first choose which objectives are most relevant to their business and then choose which SPI model is most appropriate for their organization. These two entities then drive the choice of costs, returns, and indicators. In addition, it is important to define the relationships between the objectives/benefits model and the software processes. This can be done using specific instances of the model.

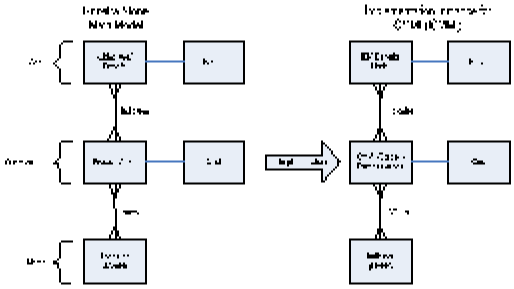

Fig. 1. Rosetta Stone objective-driven software process improvement Model (RSM)

4.2 Return, Costs and ROI

For the majority of organizations, where profit is a primary goal, benefits should ultimately lead to a monetary impact on the organization. One of the main advantages of RSM is that it is now possible to tie software process improvements to specific benefits due to the fact that the benefits defined in RSM are very granular. It must be recognized, however, that in some cases it is difficult to measure the monetary value of a benefit – for example, how can a dollar value be put on increased team morale? In the case of RSM, the return on the SPI is compared to the cost of improving the specific software process. Great care must be taken, therefore, to not only capture the monetary equivalents that accrue from the benefits of process improvement but also the cost of implementation.

5 Rosetta Stone Methodology: CMMI Implementation Instance

We demonstrate the implementation of the RSM through mapping the CMMI (staged) model to a benefits model developed by IBM Global Services, the IGSI-ISM Benefits Model [43]. The implementation of this instance is illustrated in the RHS of Fig. 1 and the final output is the RS-ICMMI.

The IGSI-ISM model (see Fig. 2) shows the relationships between the various benefits which culminate in the ultimate benefit for the organisation – *increased revenues/profits*. This benefit can be achieved through relationships between 21 separate identifiable benefit areas. These include benefits such as lower time-to-market, better risk management and competitive proposals. In addition, the model is a hierarchy of benefits – higher level benefits are derived from elements that are lower in the benefit tree. For example, *better product quality* leads to *increased productivity*. Similarly, *increasing the understanding of customer needs* leads to *setting right* *customer expectations*, thus to *improved predictability* and to *more competitive proposals*. Both *increased productivity* and *more competitive proposals* lead to an *improved image* which feeds directly to *increased revenues/profits*

The RSM requires us to map the IGSI-ISM Benefits model to the software processes whose improvements will provide these benefits. To do this, each the generic goal, specific goal and specific practice of each CMMI process area was reviewed, determining which ones have particular relevance to the IGSI-ISM benefit model. To define the mapping between objectives/benefits and software processes, a modified approach to Basili's Goal-Question-Metric approach [41], [41] is used. A *reverse mapping* between process areas (Questions) and business objectives (Goals) is created by asking what process areas (Questions) impact what business objectives (Goal). In effect, the reverse lookup asks "What objectives does this process area fulfil?"

. We note here that not all benefits are equal and the RSM differentiates between primary and secondary benefits. A *primary* benefit of a process area is one that is brought about as a direct result of implementation of that process area where the cause and effect relationship between the process area implementation and the benefit is very strong. *Secondary* benefits are those benefits which are not primary benefits and include *derived* benefits. A *derived* benefit is a benefit which is a hierarchical ancestor of either a primary or secondary benefit. As we shall see later, the benefit classification is used to determine the recommended order of process areas to be implemented.

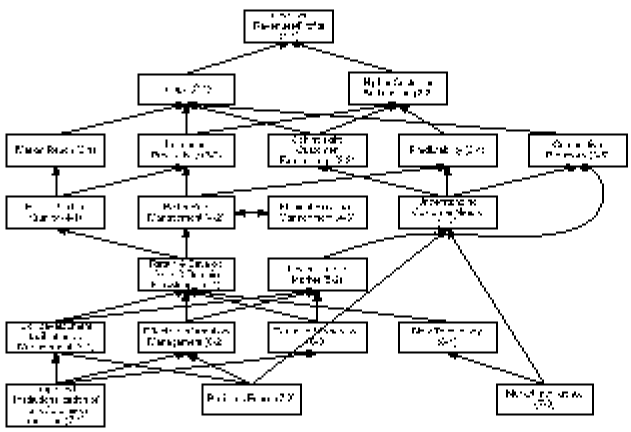

Fig. 2. IGSI-ISM Benefits Model

5.1 Examples of CMMI Level 2 Process Area to Benefit Mappings

5.1.1 Requirements Management

The Requirements Management (REQM) process area contains 1 Specific Goal (SG) which in turn consists of 5 Specific Practices (SP). The goal is that "requirements are managed and inconsistencies with project plans and work products are indentified", maintaining a current approved set of requirements over the life of the project. REQM requires the implementation of the obtaining of an understanding of requirements (SP 1.1-1), the obtaining of a commitment to requirements (SP 1.2-2), the management of requirements (SP 1.3-1), and the identification of inconsistencies between project work and requirements.

Based on the specifications of the REQM as defined by the SEI, the following are the expected primary benefits of implementing REQM:

- *Better Risk Management*: By managing requirements and identifying inconsistencies, we are better able to identify alternative strategies and avoid building software that isn't part of a customer's requirements.
- *Understanding Customer Needs*: Proper management of requirements forces us to consistently review those requirements and thus focus on understanding customer needs. By indentifying inconsistencies between requirements, plans, and work products we are constantly ensuring that the customer's needs are always foremost.
- *Lower Time to Market*: by identifying inconsistencies up front, we will spend less time working on items that are not required by customers or that are inconsistent with customers' needs and expectations. As a result, less time will be spent on rework, thus saving resources and reducing time to market.

5.1.2 Configuration Management

The purpose of Configuration Management (CM) is to establish and maintain the integrity of work products using configuration identification, configuration control, configuration status accounting, and configuration audits [44], [45]. CM consists of 3 SGs – SG1 (the establishment of baselines), SG2 (the tracking and control of changes), and SG3 (the establishment of integrity). In software projects it is absolutely essential that all artefacts are correctly baselined and tracked. Without this baselining and tracking, there is no guarantee that code, requirements or any other project artifact will be consistent with each other, thus increasing risk and reducing quality. In fact, the opposite is true, effective configuration management is essential for increasing quality and reducing risk. In addition, as [28] note, "configuration management, and in particular version control, plays a role in supporting to work of teams" and that "software configuration management serves as a mechanism for communication, change management and reproducibility."

Configuration management allows projects to properly track the various parts that make up their products. By instituting CM, multiple teams will be able to edit/modify code without stepping over each others' toes. In addition, CM allows project teams to map changes back to specific issues or requirements, this increasing product quality and managing risk. Therefore in the RS-CMMI, CM results in the primary benefits: *Better Quality Product, Better Risk Management, Teaming / Synergize*.

5.2 Achieving Specific Business Objectives

In the exemplar we have demonstrated that organisations may (normally) require increased revenues/profits, and are not particularly interested in which software process improvement methodology or software process area is used to deliver the business benefits. The process to determine which process areas to execute in order to achieve specific business benefits is as follows:

1. Determine which of the IGSI-ISM objectives that we wish to achieve. This is normally determined from outside the software process improvement group, possibly from either external clients or senior management. We will use *lower time-to-market* as the objective in this example.
2. Using the IGSI-ISM model (Fig. 2), determine which other objectives, if any, contribute to achieving our primary objective. We observe that *skill development facilitation by management, effective information management, teaming/synergize, improved institutionalization of tools/process/methods* and *business focus* all contribute to *lower time-to-market*.
3. Using the implementation mapping developed during the creation of the implementation instance of the RSM methodology, establish which process areas contribute to both the primary and secondary objectives of the selected business benefits. For illustrative purposes we will use *lower time-to-market* (node 5-2 in Fig. 2) as the example benefit we wish to achieve and have provided a reduced version of the RS-ICMMI mapping in Table 1 which contains only those process areas which have *lower time-to-market* as either a primary or secondary benefit.
4. Rank the PAs in order of relevance and implementation. There are quite a few PAs which have an effect on lower time-to-market. Most organizations have finite resources and therefore will need to prioritise their implementation. There are many different ways to rank them. More consideration should be given to those PAs that *primarily* satisfy a particularly objective. In the case of lower time-to-market, we would implement Process and Product Quality Assurance (PPQA) before implementing Configuration Management (CM) as PPQA primarily satisfies lower time-to-market while CM only secondarily satisfies lower time-to-market (see Table 1). Additionally, we should observe the software process model we are using. Although within RS-ICMMI both Requirements Management (RM) and Requirements Development (RD) directly satisfy *lower time-to-market*, as, within the CMMI staged model, RM is a Level 2 PA, it should be undertaken before RD. Using these principles, the first three process areas that

we propose implementing to *lower time-to-market* from the Level 2 Process Areas would be Requirements Management, Supplier Agreement Management, Measurement and Analysis and Process and Product Quality Assurance. Configuration Management would not be implemented until later as lower-time-time market is only a secondary benefit. By ordering implementation based on relevance, as above, we ensure that those process areas are implemented which have most impact on the business objective. As a result, we implement those process areas up front which provide biggest bang for the buck for the business objective desired.

We must recognize, however, that this proposed methodology is not without its limitations. From a practical perspective, while both the methodology and the RS-ICMMI implementation instance have been reviewed at length by practitioners, it has not yet been actually put into practice. Another challenge is that this research has taken place over several years and one of the challenges is to keep the RS-ICMMI model up to date with the latest version of CMMI. Finally, while the IGSI-ISM Benefits model is a good generic business objectives model there are many organizations out there which do not follow a for-profit business model such as represented by the IGSI-ISM model. Further research may be appropriate to bring in other types of benefits model.

Table 1: Example Objective - Lower Time to Market

Staged Level	Process Area	Expected Primary IGSI ROI Benefits	Expected Secondary IGSI ROI Benefits
2 - Managed	Requirements Management	4-2, 4-4, 5-2	7-3, 5-1, 4-3, 3-4, 3-5, 2-1, 2-2, 1-1
	Supplier Agreement Management	5-2, 4-1, 4-2, 3-4	3-1, 3-2, 3-3, 3-4, 2-1, 2-2, 1-1
	Measurement and Analysis	5-2, 4-1, 4-2, 3-4	3-1, 3-2, 3-3, 3-4, 2-1, 2-2, 1-1
	Process and Product Quality Assurance	7-1, 5-2, 4-1, 4-2, 3-4	6-1, 6-2, 6-3, 5-1, 5-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
	Configuration Management	6-3, 4-2, 4-1	5-1, 5-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
3 - Defined	Requirements Development	5-2, 4-1, 4-2, 4-4,	4-3, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
	Organizational Process Focus	7-1, 7-2, 7-3	6-1, 6-2, 6-3, 6-4, 5-1, 5-2, 4-1, 4-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
	Organizational Process Definition	7-1, 6-2	6-1, 6-3, 5-1, 5-2, 4-1, 4-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
	Organizational Training	6-1, 6-3	5-1, 5-2, 4-1, 4-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
	Integrated Project Management	6-3, 4-1, 4-2, 4-3, 4-4	5-1, 5-2, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
	Integrated Project Management for IPPD	6-3, 4-1, 4-2, 4-3, 4-4	5-1, 5-2, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
	Integrated Teaming	6-3, 6-2, 4-1, 4-3, 4-2, 4-4	5-1, 5-2, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
	Integrated Supplier Management	7-2, 7-3, 6-3, 6-4, 5-2, 4-1, 4-2, 3-4	5-1, 5-2, 4-3, 3-1, 3-2, 3-3, 3-5, 2-1, 2-2, 1-1
	Organizational Environment for Integration	7-1, 7-2, 6-2, 6-3, 5-2	6-1, 6-2, 6-4, 5-1, 5-2, 4-1, 4-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
4 - Quantitatively Managed	Organizational Process Performance	7-1, 7-2, 7-3, 6-2	6-1, 6-3, 5-1, 5-2, 4-1, 4-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
	Quantitative Project Management	5-2, 4-1, 4-2, 4-3	4-3, 4-4, 2-1, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
5 - Optimizing	Organizational Innovation and Deployment	7-1, 7-2, 7-3	6-1, 6-2, 6-3, 6-4, 5-1, 5-2, 4-1, 4-2, 4-3, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 2-2, 1-1
	Causal Analysis and Resolution	7-1, 6-2, 5-2, 4-1, 4-2, 4-3	6-1, 6-3, 5-1, 4-4, 3-1, 3-2, 3-3, 3-4, 3-5, 2-1, 3, 1-1

6 Conclusion

The purpose of this research was to develop a generic methodology that allows organizations to achieve specific business-focused objectives by implementing various existing and proven SPIs. While a business-driven approach to SPI is research-worthy in itself, in order for such a model to be successful in the real world it should be flexible enough to be able to support the sometimes vastly different organizational objectives of various types of business – government organizations, non-government organizations (NGOs), the military, and for-profit commercial companies to name but a few. Not only should it be flexible enough to support these various organization types, but it should also be customizable so that individual organizations are able to customize benefit models. In addition, as an enormous amount of effort has been spent on SPI and SPI research, any proposed model should leverage existing work as much as possible. In order to meet these objectives the Rosetta Stone methodology was developed. It is a generic benefits-driven methodology which, in its essence, allows practitioners to map from a benefits model which is appropriate to an organization to a proven SPI methodology. In addition, is it fully customizable and allows organizations to make adjustments to the model where they feel it appropriate.

This research has brought together business focus and SPI. Two business-focused SPI models are presented – the RSM meta-model which maps from arbitrary benefits models to arbitrary SPI models and the RS-CMMI model which maps from the IGSI-ISM benefits model to the CMMI (Staged) model. We are currently evaluating both models through case study research with software process practitioners.

Acknowledgement

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Appendix I EuroSPI 2010 Conference Paper

The following paper was accepted for the EuroSPI conference at the Grenoble Institute of Technology in September 2010.

The Rosetta Stone Methodology – A Benefits-driven Approach to SPI

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Abstract. The Rosetta Stone Methodology (RSM) has been developed which allows organizations to undertake Software Process Improvement (SPI) based on business- and organizational-driven goals and objectives. The methodology itself is fully customizable and allows organizations to make adjustments to the model where they feel it appropriate. To demonstrate the usefulness, appropriateness and practicality of this new approach, the Rosetta Stone IGSI-ISM to CMMI Instance mapping (RS-ICMMI) is developed. To aid in understanding, the Measurement and Analysis (MA) process area is used as an example of how to apply the methodology. The Rosetta Stone Methodology and the RS-ICMMI instance have been validated by experts.

1 Introduction

According to the Organization for Economic Co-Operation and Development [1], total worldwide spending on ICT was expected to reach $2.964 trillion in 2005, the last year for which the OECD has published estimates. Given the massive amount of spending involved, anything which can shave even a few percentage points off costs could potentially free up a large amount of capital that could be re-invested in the organization. From a Software Process Improvement perspective, there are several competing and, in some cases, complementary standards such as the Software Engineering Institute's CMMI for Development version 1.2 [2], the International Standards Organization's (ISO) 15504 [3], and the International Standards Organisation's ISO 9000-3 [4] and ISO 9001:2000 [5] standards, a process-driven approach to define, establish and maintain software quality within an organization that will allow organizations to meet their business objectives [6].

Following our literature review, we can summarise software process improvement benefits into the following categories:

- **Return on Investment (ROI)**: We have noted evidence of a correlation between increased ROI and implementation of various SPI initiatives. Examples of studies which illustrate increased ROI are Hughes Aircraft (Humphrey et al. [7]), Boeing STS, a division of Boeing Inc. [8], Oklahoma City Air Logistics Center (OC-ALC) [9].
- **Productivity**: There are many studies which demonstrate that productivity increases as a result of software process improvement. These include Brodman and Johnson [10], Dion [11], and Herbsleb et al. [12].

- **Quality**: Studies analysed demonstrate that as organizations implement more quality-oriented processes, the quality of code improves. Additionally, quality increases as process capability maturity levels increase. Studies in this area include Krasner, Pyles et al. [13] and Putnam and Myers [14]. We also note that it becomes more difficult, and therefore more costly, to increase quality between higher maturity levels.
- **Financial Benefit:** Evidence of the financial benefit resulting from the implementation of SPI may be expressed as a ratio of cost to benefit (or vice versa) or as a discussion of costs and benefits separately, and published research tends to centre on ratios rather than on costs and benefits. Example studies include the SEI [15] and Sapp, Stoddard et al. [16].

All these initiatives have demonstrated improvement in an organization's systems capabilities but these improvements were approached from an IT perspective. There is no ability within the established methodologies to define what benefits/objectives an organization would like to achieve and use business-centric objectives to drive what particular SPI initiatives should be undertaken. We also note that IT organizations have tended to drive the SPI agenda in order to achieve IT benefits as a primary objective, and organizational benefits as a secondary objective. However, this is typically not the way the commercial world works – in the commercial world it is the business which drives IT, not the other way around. The Rosetta Stone Methodology (RSM), which we developed and validated during this research, allows businesses to undertake business- and organizational-driven goals and objectives using SPI. In addition, we present a specific instance of the RSM, the RS-ICMMI (Rosetta Stone - Implementation for CMMI) mapping, presenting details on the Measurement and Analysis (MA) process area.

Section 2 of this paper describes the Research Methods used in developing both the meta-model and the operationalisation of the methodology. Section 3 describes the Rosetta Stone meta-model. This meta-model provides an abstract representation of the relationships between business objectives, software process improvement process areas, and the indicators/metrics which may be used to demonstrate progress or regression of the implementation of SPI within an organization. Section 4 describes the methodology used to arrive at a concrete implementation of the meta-model. In section 5 we create an instance of a mapping. The implementation presented here is a mapping from the IGSI-ISM benefits model, a generic benefits model developed by IBM India [17], to the CMMI (Staged) SPI model and will hereafter be referred to as the Rosetta Stone IGSI-ISM to CMMI implementation or RS-ICMMI for short. We discuss the validation of this model through interviews with experts. Section 6 concludes the paper.

2 Research Methods

Once we had established through literature review and expert interviews that there was no readily usable approach which supported businesses in deciding which software processes to improve to gain specific business benefits, we commenced the development of an objectives-driven approach whose use should allow this. The first step was to create a generic methodology, the Rosetta Stone Methodology (RSM). This was done by creating a meta-model of all the elements involved in an SPI implementation. After this, a step-by-step approach was developed which guides practitioners in using an SPI methodology combined with a benefits model. We defined a mapping between business-focused benefits and individual SPI process areas. In essence, this process allows practitioners to substitute the meta-model with a concrete implementation instance of the model. This mapping is then used as the basis to decide upon and prioritise which process areas should be implemented to achieve specific business benefits.

To demonstrate the implementation of the RSM in a specific instance, we investigated available return on investment (ROI) models which did not deal exclusively with software process improvement, but with which existing SPI models could be combined. We chose to work with the IGSI-ISM Benefits Model [17] and CMMI Version 1.2 [7] This is done as follows:

1. Define the mapping (relationships) between Objectives/Benefits and Software Processes
2. Answer the questions that are relevant to the individual organization.

The initial methodology, meta-model and implementation instance were developed as described and were then reviewed by a small group of peers for validity. For triangulation purposes, they were validated through an expert panel review of 17 people with an average work experience in the software industry of 19 years along with an average of 11 years of SPI experience. Additionally, to validate the implementation instance, a group of experts was interviewed about each relationship within the RS-ICMMI model. Out of a pool of ten experts, two experts were randomly selected to review a set of IGSI-ISM Benefit/CMMI Level 2 combinations. They discussed whether they agreed with the relationship presented, and where they had seen these relationships work in practice. This process was repeated until all combinations had been reviewed. In some cases, the RS-ICMMI was modified as a result of these interviews.

3 Rosetta Stone Meta-Model

Many valuable studies of the benefits resulting from implementation of CMM/CMMI and Software Process Improvement (SPI) in general have been undertaken over the last several years. These studies have focused on SPI along one or two of three aspects – organizational, improvement methodology, or metric-based. In contrast, our research has developed a consolidated model which would allow practitioners to view organization, improvement programs and metrics concurrently using one, unified framework – a "Rosetta Stone", if you will, of SPI.

The Rosetta Stone meta-model is composed of 5 basic elements, as well as the relationships between them (Figure 1), with further detail in [18].

- Elements: The most important element is the *set of Business Objectives* or *Benefits* which an organization wishes to achieve. Ideally, these should be hierarchical so that the achievement of one leads to the achievement of others.
- Relationships are defined between Business Objectives and Process Areas (PAs).
- Return, Costs and ROI: it is now possible to tie SPI to specific benefits due to the fact that the benefits may be defined at a very granular level.

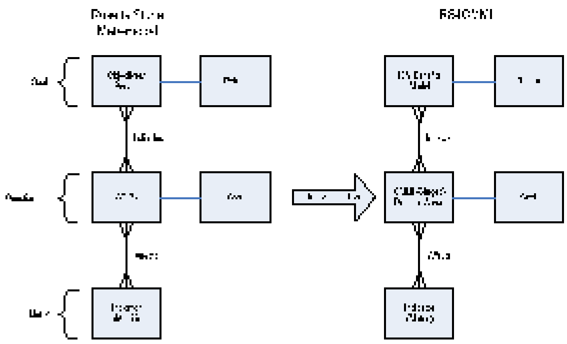

Figure 1: Rosetta Stone Meta-Model and Implementation Mapping

4 The Rosetta Stone Methodology

The Rosetta Stone methodology is the translation process whereby an abstract meta-model is transformed into a concrete implementation which may be readily used by practitioners. At a high level, each abstract entity as described in Figure 1 must be replaced with a concrete entity. Frequently the choice of both the SPI methodology (Step 1) and benefits model (Step 2) is performed at a strategic level within an organization. The mapping between benefits and process areas (step 3), the determination of the implementation order (step 4) and the determination of which metrics to use (step 5) are performed by SPI practitioners; and the monitoring of costs and benefits (step 6) is performed by the "front-line" staff involved in the running of projects and support organizations.

Step 1 – Choose the SPI Methodology: There are several SPI models and methodologies currently in use within ICT and several factors influence an organization's decision on which SPI methodology to use. Reasons for SPI implementation include improving the software process, external requirements such as supplying a contract, and enabling the business in a particular market segment.

Step 2 – Choose the Benefits Model: Different organizations have different organizational goals and missions. Some, like IBM and Microsoft, are for-profit companies while others such as universities, charities, and local government bodies have different goals and missions. What both the for-profit and not-for-profit organizations have in common, however, is that both types of organization try to use their use their resources most efficiently to achieve their organizational objectives.

Step 3 – Mapping between the SPI Methodology and the Benefits Model: One of the core questions we asked is how do we determine the benefits associated with the implementation of a Process Area? This is based on the Goal Question Metric (GQM) approach [19-22] and is performed by creating a mapping between Goals (Business Objectives) and Questions (Process Areas) using a reverse mapping between Process Areas (Questions) and Business Objectives (Goals).

Step 4 – Determine Implementation Order: This step allows us to determine which Process Areas should be implemented, and in what order, to achieve those specific business benefits. A prerequisite for this step is an understanding of what business objectives an organization wishes to achieve. This understanding may come from many sources – for example, a Six Sigma review of existing business processes. Given that an organization knows what business objectives it wishes to achieve, it must then use the map which was built up in Step 3 to determine which Process Areas contribute to the desired business objective.

Step 5 – Identification of Metrics/Indicators for Benefits: The organization has now decided which business objectives it wishes to achieve. Each potential benefit must be capable of being monitored in order to determine if the benefit is being received by the organization or not. GQM [19-22] is a well-established methodology for defining measurable goals and has been used to establish successful measurement programs in industry. Specifically with regard to the Rosetta Stone Methodology, each Goal is the analysis of a particular Benefit from the Benefits model. The Question is "what are the objective measures which can be used to determine if a benefit is being achieved?" and the Metrics are "what is going to be measured?".

Step 6 – Tracking of Costs and Returns: The final step involves tracking both the Costs and the Returns and is operational in nature. This step will typically be performed by the front-line staff involved in developing software such as the Project Management Office, the development staff, and the QA staff. Note that, as this step has not been implemented as part of this work, this step will not be discussed in Section 5.

5 Operationalization of the Rosetta Stone Methodology

Having discussed the methodology at a high level in section 4, we now present a specific instance of operationalizing the methodology.

Step 1 – Choose SPI Methodology – CMMI (Staged): In this paper, we present SEI's CMMI (Staged) methodology [23] as the demonstration SPI. It was chosen primarily as it is one of the most popular SPI methodologies in use today and is therefore widely understood and used by many practitioners.

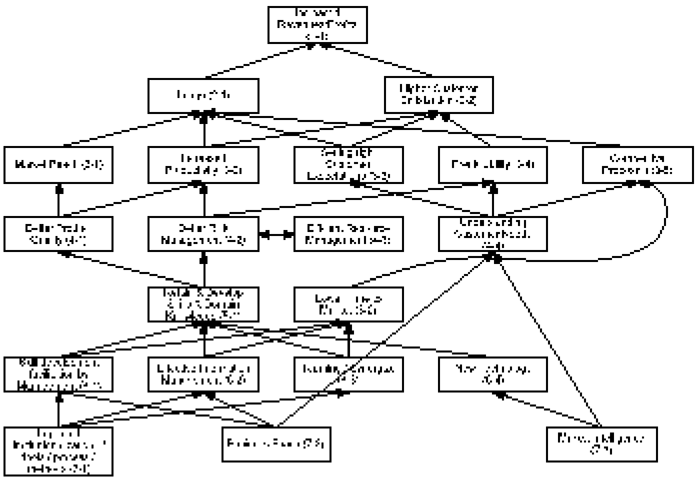

Figure 2: IGSI-ISM ROI Model

Step 2 – Choose Benefits Model – IGSI-ISM Benefits Model: Goyal at al. [17] developed a generic for-profit benefits model, with the ultimate goal being an increase in revenues/profits and which will appeal to a broad spectrum of for-profit organizations – the IGSI-ISM model. This model, shown in Figure 2, determines 21 separate identifiable benefit areas[1], and the relationships between them. This model is

[1] We recognize that there are some benefits which are not described as we might like within this model. An example is 'Image' which should read 'Improved Image'. We have not clarified such changes in this paper.

a hierarchy of benefits – higher level benefits are derived from elements that are lower in the benefit tree. Not all benefits are equal and the model differentiates between primary and secondary benefits. A *primary* benefit of a Process Area is one that is brought about as a *direct* result of implementation of a process area where the cause and effect relationship between the Process Area implementation and the benefit is very strong. *Secondary* benefits are those benefits which have a secondary impact or which are *derived* as a result of achieving another benefit. A *Derived* benefit is a benefit which is a hierarchical ancestor of either a primary or secondary benefit. For example, using Figure 2, if Better Product Quality (4-1) can be achieved, this will lead to Increased Productivity (3-2). We refer to Better Quality Product (4-1) as a primary benefit and Increased Productivity (3-2) as a derived benefit. As Increased Productivity (3-2) is a derived benefit of Better Quality Product (4-1), it is also classed as a secondary benefit

Step 3 – Map between SPI Methodology and Benefits Model: To arrive at the mapping, each PA and its associated Generic Goals (GGs), Specific Goals (SGs), and Sub-Processes (SPs), with [24] as the reference document, were reviewed. This allowed us to determine which ones have particular relevance to the IGSI-ISM benefit model. In effect, we questioned "What objectives does this PA answer?" As a demonstration of how the mapping was created we illustrate using the CMMI Level 2 Process Area – Measurement and Analysis (MA).

Measurement and Analysis (MA)

Definition

The purpose of Measurement and Analysis (MA) is to develop and sustain a measurement capability that is used to support management information needs [25]. MA consists of 2 specific goals (SG) – the alignment of Measurement and Analysis activities (SG1) and the obligation to provide measurement results (SG2). Measurement and analysis of appropriate metrics is essential in order to provide feedback to an organization on the current and potential future state of a project. SG1 provides several important specific practices (SP) to enable the benefits described below. In particular, it provides for the specification of metrics (SP 1.2-1), the specification of data collection and storage procedures (SP 1.3-1), and the specification of analysis procedures (SP 1.4-1). SG2 in general provides for the feedback loop to enable an organization to act on the results of the results obtained in SG1.

Expected Benefits

MA involves the creation and reporting of various metrics to support management information needs. Such metrics will allow a project team to review important information with regard to the progress of a project. This will allow them to adapt their strategies to most efficiently bring a project to market. Therefore, Lower Time to Market (5-2) is a primary beneficiary of MA. We identified Better Quality Product (4-1) as another primary beneficiary, as product metrics such as quality are a major factor in establishing the quality of a product. With such metrics, it is possible to alter processes and procedures to increase the quality of products. Without the ability to measure various facts, it would be virtually impossible to determine if a project is at risk. Once a project team is aware of a risk, only then can they remediate the risk. Thus MA provides a project team the ability to better manage risk. Therefore MA provides a primary benefit to Better Risk Management (4-2). Predictability (3-4) is also a primary benefit. This is because Predictability is gained when, over time, accurate measurements are taken of various aspects of projects. Only when accurate measures are available, is it possible to predict costs, times, and quality. By developing and maintaining a measurement capability within a project and organization, we will enable the organization to quantify various aspects of the whole development lifecycle. This will allow the organization to see where certain elements break down and do not live up to their full potential. As a result, the organization should be able to make appropriate changes to projects and processes to product better quality products, better manage risk, lower time to market, and increase predictability.

When we validated Measurement and Analysis (MA), both interviewees, based on their experiences, agreed with the model. With regard to the impact of MA on Better Quality Product (4-1), the first interviewee stated that, in his experience, projects that aren't measured tend to bow to pressures about release dates while the second interviewee has specific experience that shows when people are aware they're being tracked, they change their mindsets and consequently improve the quality of the product being produced. The second interviewee stated that MA impacts Predictability directly. According to him, he has seen that if you don't have historical data then "project planning is more of an art than a science."

The only non-derived (secondary) benefit of MA was Setting Right Customer Expectations (3-3). This is because one of the most important factors in setting the right customer expectations is in ensuring predictability – a product should be ready when an organization says it should be ready. One of the main elements in aiding predictability is the collection of metrics across various projects which will allow an organization to create an organizational metric database. This database will aid in increasing predictability and, as a result, help in setting the right customer expectations.

When we validated the model with two interviewees discussing each relationship, we found that

- 10 combinations are 100% compliant with the original mapping
- 6 combinations are 50% compliant with the original mapping
- 2 combinations are 0% compliant with the original mapping

There were 6 Process Area/Benefit combinations which were 50% compliant with expectations. In stating that there is a positive cause and effect relationship between MA and Competitive Proposals (3-5), the second interviewee states that it makes sense because if you measure accurately, you put just the right amount of resources in place and therefore cut down on waste. This then leads to competitive proposals. Again according to the second interviewee, there is a positive correlation between MA and Skill Development Facilitation by Management (6-1). The reason that the interviewee gives for this is that if accurate measurements are taken of the development process and specific components are buggy, the developers writing the buggy code may be identified and targeted training can then be given to the developers in question. The same interviewee also states that there is a positive correlation between MA and Teaming/Synergize (6-3) as he saw this effect in a consulting firm he worked for when low-level measurements were being taken on a daily basis. The second interviewee thought that there was a logical positive relationship between MA and New Technology (6-4).

Expected Primary Benefits	Expected Secondary Benefits
Lower Time To Market (5-2) Better Quality Product (4-1) Better Risk Management (4-2) Predictability (3-4)	Improved Institutionalization of Tools/Process/Methods (7-1) Skill Development Facilitation by Management (6-1) Efficient Information Management (6-2) Retain and Develop Skills and Domain Knowledge (5-1) Market Reach (3-1) Setting Right Customer Expectations (3-3) Competitive Proposals (3-5) Image (2-1) Higher Customer Satisfaction (2-2) Increased Revenues/Profits (1-1)

Table 1: Post-validation Expected Benefits of Measurement and Analysis

The complete list for Measurement and Analysis after validation is given in Table 1. There were 2 combinations which were 0% compliant with expectations. For the relationship between MA and Market Reach (3-1), the second interviewee did not feel she was competent to answer this question and, in order to be consistent with how weak or inconclusive answers are dealt with, the answer was deemed to be a "no." For the relationship between MA and Improved Institutionalization of Tools/Process/Methods, (7-1) both interviewees disagreed with expectations. The second interviewee's analysis was that if things are being measured and analysed, issues (if there are any) will be seen. This may in turn lead to institutionalization of new technology or methods in order to solve the issues.

Step 4 – Determine Implementation Order: In many cases, organizations are not so much concerned with faithfully implementing all CMMI Levels or all PAs as they are with achieving specific results within a mature and repeatable framework. Examples of specific results that organizations may want to achieve are Increasing Productivity and/or Lowering Time to Market.

The process to achieve this is as follows:
1. Determine which of the IGSI-ISM objectives that we wish to achieve
2. Using the IGSI-ISM model, determine which other objectives, if any, contribute to achieving our primary objective
3. Establish which PAs contribute to both the primary and secondary objectives and rank the PAs in order of relevance and implementation

Determine the IGSI-ISM Primary Objective to achieve. The choice of which IGSI-ISM objective to aim for is usually determined for us by outside forces such as senior management or, in some cases, external clients. For this example we discuss Lower Time to Market (5-2).

Determine IGSI-ISM objectives contribute to the Primary Objective. From the IGSI-ISM model (see Figure 2), Lower Time to Market (5-2) depends on the lower-level objectives of Skill Development Facilitation by Management (6-1), Effective Information Management (6-2), Teaming/Synergize (6-3) and Improved Institutionalization of Tools/Process/Methods (7-1).

Determine which PAs contribute to IGSI-ISM Objectives and rank them for implementation. Based on the full analysis of RS-ICMMI, there are several PAs which have an effect on Lower Time to Market (5-2). Most organizations have finite resources and so will not be able to implement them all concurrently so we are forced to prioritize them for implementation. There are many different ways to rank them but there are two very important factors to keep in mind when deciding on an order. Firstly, more consideration should be given to those PAs that primarily satisfy a particular objective. By this we mean that those PAs that satisfy an objective as a primary objective should be given higher ranking than those that do not. For example, both Process and Product Quality Assurance (PPQA) and Configuration Management (CM) both help to us attain Lower Time to Market. PPQA has Lower Time to Market as a primary objective while CM does not. As a result, PPQA should be implemented before CM. The reasoning behind this is that PPQA fully satisfies the Lower Time to Market objective while CM satisfies the Teaming/Synergize (6-3) objective which is only a contributing objective to Lower Time to Market. Secondly, more consideration should be given to those PAs that, in the Staged Model, are lower in the Stage phases. For example, both Requirements Management and Requirements Development directly satisfy Lower Time to Market but, as Requirements Management is a Level 2 PA, it should be undertaken before Requirements Development.

Using these principles, the recommended order for implementation of four Process Areas to improve Time to Market would be:

- Requirements Management;
- Supplier Agreement Management;
- Measurement and Analysis;
- Process and Product Quality Assurance.

Step 5 – Identify Metrics for Benefits: Metrics which may be used to determine if an organization is succeeding in achieving its business objectives should be identified. A given metric may be associated with one or more benefits and a given benefit may be associated with one or more metrics. As a result, a metric may appear as an indicator for more than one benefit. For example, to measure the Better Quality Product (4-1), possible metrics include defect density at various phases in the lifecycle, costs due to lack of quality [26], loss of reputation to the firm, any lost bids, software reliability, software rate of change [27], or increase/decrease in software complexity [28].

6 Conclusion

The RSM methodology is a flexible and straight-forward methodology that can be readily and easily modified by practitioners to fit their own particular needs. The RS-ICMMI instance presented uses an industry-standard SPI model and is of immediate use by practitioners with little, if any, modification. In addition, by describing in abstract terms what a metric/indicator is, what a generic benefit/objective is, what an SPI is, and the relationships between them, the door is open for practitioners to use the model on whatever SPI initiative of choice they wish to implement. Finally, the model is highly extensible in that practitioners can add their own metrics and benefits/objectives either as replacements or in addition to the ones currently described in the RS-ICMMI implementation instance. In short, RSM model is truly a Rosetta Stone Methodology allowing personnel in the field to freely translate between SPIs, Benefits/Objectives, and Metrics.

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