ASSESSING THE MATURITY OF SOFTWARE TESTING SERVICES: A MODEL AND ITS INDUSTRIAL EVALUATION

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ASSESSING THE MATURITY OF SOFTWARE TESTING SERVICES: A MODEL AND ITS INDUSTRIAL EVALUATION

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ABSTRACT

ASSESSING THE MATURITY OF SOFTWARE TESTING SERVICES: A MODEL AND ITS INDUSTRIAL EVALUATION

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While many companies conduct their software testing activities in-house, many other companies outsource their software testing needs to other firms who act as software testing service providers. In the context of software testing services, there could be various challenges and as a result the quality of services is not always as expected. Thus, it is important, for both providers and also customers of services, to assess the quality and maturity of test services and subsequently improve them. This thesis proposes a maturity model for software testing services (called MM-TSVC) which has been developed based on the principles of the 'CMMI for Services' (CMMI-SVC) model and in close collaboration with several industry partners offering software testing services. To assess the applicability and usefulness of the model, the model was evaluated in two industrial settings by applying it in two companies who provide software testing services in Turkey. The quantitative and qualitative results of the case study have shown that the proposed model has been helpful for both of the companies and their managers by helping them objectively assess the maturity of their testing services and also to pinpoint potential improvement areas.

Keywords: Software testing; software testing outsourcing; software testing services; service quality; service maturity; test maturity; test process assessment; test process improvement; industrial evaluation; industrial case study

ÖZ

YAZILIM TEST SERVİSLERİNİN OLGUNLUK DEĞERLENDİRMESİ: BİR MODEL VE BU MODELİN ENDÜSTRİYEL ÖLÇÜMÜ

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Birçok şirket yazılım test ihtiyaçlarını kendi içlerinde hallederken, büyük bir çoğunluktaki şirketler ise yazılım test ihtiyaçlarını dışarıdaki hizmet sağlayıcıları vasıtasıyla karşılamaktadır. Yazılım Testi hizmeti alımı esnasında beklenmedik çeşitli zorluklarla karşılaşılabilmektedir. Bu durum, servis sağlayıcılarının ve test hizmeti alan müşterinin hizmet kalitesini ve hizmet olgunluğunu ölçmek için önemli bir husustur. Bu tez, yazılım test hizmetleri sunan çeşitli endüstri ortaklarının önerileri ve 'Servisler için Uyumluluk Olgunluk Modeli Entegrasyonu' (CMMI-SVC) modeli baz alınarak geliştirilen 'Yazılım Test Servisleri için Olgunluk Modeli' ni (bundan sonra MM-TSVC olarak anılacak) içermektedir. Modelin uygulanabilirliğini ve yararlılığını değerlendirmek için, model Türkiye'de Yazılım Test Hizmetleri sağlayan iki şirkette uygulayarak endüstriyel uygunluğu değerlendirilmiştir. Bu vaka çalışmasının nitel ve nicel sonuçları, önerilen modelin test yöneticilerine ve test hizmeti sağlayan firmalara yardımcı olduğunu göstermektedir.

Anahtar Kelimeler: Yazılım Testi; dış kaynaklı yazılım testi; yazılım testi servisleri; servis kalitesi; servis olgunluğu; test olgunluğu; test süreç değerlendirmesi; test süreç iyileştirmesi; endüstriyel değerlendirme; endüstriyel vaka çalışması

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LIST OF ABBREVIATIONS

CMM	Capability Maturity Model
CMMI	Capability Maturity Model Integration
CMMI-ACQ	Capability Maturity Model Integration for Acquisition
CMMI-DEV	Capability Maturity Model Integration for Development
CMMI-SVC	Capability Maturity Model Integration for Services
IEC	International Electrotechnical Commission
ISO	International Standards Organization
ISTQB	Software Testing Qualifications Board
ITIL	Information Technology Infrastructure Library
PA	Process Area
RQ	Research Question
SG	Specific Goal
SLR	Systematic Literature Review
SP	Specific Practise
TMA	Test Maturity Assessment
TMMI	Test Maturity Model Integration
TPI	Test Process Improvement

CHAPTER 1

INTRODUCTION

Software testing is an impotent while a costly phase of the software development life-cycle. A 2013 study by the Cambridge University [1] states that the global cost of detecting and fixing software defects has risen to $312 billion annually and it makes up half of the development time of the average project.

According to various studies, e.g., [2-4], software testing practices and processes in many companies are far from being mature and are usually conducted in ad-hoc fashions. Such immature practices lead to various negative outcomes, e.g., ineffectiveness of testing practices in detecting all the defects, and cost and schedule overruns of testing activities. Also, testing is often conduct not efficiently, e.g., "*The costs of testing of a software project or product are considerable and therefore it is important to identify process improvement propositions for testing*" [5].

While many companies conduct their software testing activities in-house, there are many other companies who outsource their software testing needs to other firms, usually dedicated to providing software testing services [2-4, 7-10]. In the software testing services, there are challenges and, thus as a result, the quality of test services is not always as expected by service clients. Thus, it is important, for both providers and also customers of services, to assess the quality and maturity of test services and subsequently improve them.

Test Maturity Assessment (TMA) and Test Process Improvement (TPI) are two active areas among both researchers and practitioners. To improve the quality of technical software testing activities (e.g., test-case design, usage of test metrics), various TMA and TPI models and approaches been proposed by practitioners and researchers. For example, a 2014 book entitled "*Improving the Test Process: Implementing Improvement and Change*" [6] by the International Software Testing Qualifications Board (ISTQB) suggest various approaches in this context.

As part of this thesis, a recent Systematic Literature Review (SLR) study was conducted on the subject of TMA and TPI [11] (also see the online paper pool at: https://goo.gl/zMnQfN). The SLR systematically selected and reviewed 181 studies on the topic, and identified 58 different test maturity models. Also another recent

2016 SLR [12] on this topic identified 18 test process improvement approaches showing the fast progress of this important field in software testing. Although many test maturity models have been proposed, but as of this writing, no maturity model has been proposed for assessment of software testing 'services' and that is the goal of the research reported in this work.

In the course of many (20+) industry-academia collaborative projects in software testing, e.g., [27-31] (both ongoing and also in the past), the authors have observed that many companies have the need for assessing maturity of software testing services. Based on an the principles of "action research" [32, 33], and a technology transfer model proposed by Gorschek et al. [34], those motivations arose the need for the current study and the proposed maturity model for software testing services (called *MM-TSVC*) that was developed and is reported in this thesis.

The MM-TSVC model has been developed in close collaboration with several industry partners offering software testing services and based on the structure of the 'CMMI for Services' (CMMI-SVC) model [13, 24] which itself is a member of the CMMI family of maturity models (Capability Maturity Model Integration) [25]. The MM-TSVC model has five maturity levels and is composed of several process areas in each level. MM-TSVC can be used by three types of audience: (1) test service providers, (2) test service clients, and (3) independent service assessors. Similar to the motto of CMMI-SVC*: "Improving processes for providing better services"* [13], the main goal of MM-TSVC is to help test service providers to improve their processes for providing better services. Test service clients can also use this model to assess the quality of the services that they receive. Independent service assessors can use the model to assess the quality of service provided by third party providers.

The remainder of this paper is structured as follows. A review of the background and related work is presented in Section 2. Section 3 presents the core concepts of the proposed maturity model (MM-TSVC). Section 4 presents a case study in which the model is applied to two companies providing software testing services to assess the applicability and usefulness of the model. Finally, in Section 5, conclusions are drawn, and areas for further research are suggested.

1.1 Background and Related Work

I review in this section first the state-of-the-art in test maturity assessment and test process improvement and then raise the need for assessing maturity of software testing services.

Since the scope of this work is maturity of software testing services, then two categories of maturity models were reviewed:

- Relevant test maturity models, e.g., Test Maturity Model integrated (TMMi) [3, 4] and the Test Process Improvement (TPI) model [5]
- Relevant service maturity models: ISO/IEC 20000 [6], Information Technology Infrastructure Library (ITIL) [7], CMMI for Services [2]

1.2 State-of-the-art in Test Maturity Assessment and Test Process Improvement

Test maturity assessment and test process improvement are two active areas among both researchers and practitioners. As part of this thesis, a recent Systematic Literature Review (SLR) study was conducted (see the online paper pool at: https://goo.gl/zMnQfN) on the subject of test maturity assessment and improvement. The SLR systematically selected and reviewed 181 studies on the topic, and identified 58 different test maturity models. Also a recent 2016 SLR [1] on this topic identified 18 test process improvement approaches showing the fast progress of this important field in software testing.

Due to space constraints, I do not list all the 58 test maturity models in my thesis, but only present a few examples in Table 1, while the full list can be found in the online spreadsheet[8]. I also mention the levels of the 'staged' TMA/TPI models in Table 1.

In terms of popularity, TMMi (and its earlier version TMM), [Source 127] in the online spreadsheet [8], and TPI (and its successor TPI-Next) [Source 74] are the most popular models. TMMi and TMM have been used for assessments or as base models in 58 sources while TPI and TPI-Next have been used for those purposes in 18 sources. 28 sources used other models for TMA/TPI, e.g., TestSPICE [Source 93, 122, 145, 147], TMap [Source 157].

Table 1 Examples of the test maturity models proposed in the community along with their maturity levels

Test Maturity Model integration (TMMi) [Source 127] • Level 1: Initial • Level 2: Definition • Level 3: Integration • Level 4: Management and measurement • Level 5: Optimization	TPI (Test process improvement) [Source 74]: a 'continuous' model, i.e., not 'staged' (based on maturity levels), but including 20 Key Performance Areas (KPAs). Each KPA has four levels: A...D 1. Test strategy 2. Life-cycle model 3. Moment of involvement …. 18. Test process management 19. Evaluation 20. Low-level testing	Unit Test Maturity Model [Source 156] • Level 0: Ignorance • Level 1: Few simple tests • Level 2: Mocks and stubs • Level 3: Design for testability • Level 4: Test driven development • Level 5: Code coverage • Level 6: Unit tests in the Build • Level 7: Code coverage feedback Loop • Level 8: Automated builds and tasks
Agile Quality Assurance Model (AQAM) [Source 3] • Level 1: Initial • Level 2: Performed • Level 3: Managed • Level 4: Optimized	Automated Software Testing Maturity Model (ASTMM) [Source 5] • Level 1: Accidental automation • Level 2: Beginning automation • Level 3: Intentional automation • Level 4: Advanced automation	TPI-EI [Source 24] Adaptation of TPI for embedded software
Agile Testing Maturity Model (ATMM) [Source 35] • Level 0: Waterfall • Level 1: Forming • Level 2: Agile bonding • Level 3: Performing • Level 4: Scaling	Test SPICE [Source 93] A set of KPAs. Based on ISO/IEC 15504, Software Process Improvement and Capability Determination (SPICE) standard	The Personal Test Maturity Matrix [Source 151] A set of KPAs such as: test execution, automated test support and reviewing

The development of models are observed such as TPI-EI [Source 24] which is the adoption of the TPI model in the embedded software domain, the Unit Test Maturity Model [Source 156], or the Personal Test Maturity Matrix [Source 151] which is used to gauge test engineers' maturity and capability development. After reviewing the technical details of several models, authors observed that clearly many aspects in various models overlap.

According to many sources (e.g., [1]), TMMi [3, 4] and TPI [5] (and its newer version TPI-Next [9]) are the most popular and widely-used models and approaches in this area. I provide a brief overview of TMMi and TPI in the following.

1.2.1 Test Maturity Model Integrated (TMMi)

TMMi is based TMM itself, itself based on the Capability Maturity Model (CMM) and CMMI, and was first proposed in 1998 [10]. The latest version of TMMi specification as of this writing is 1.0 [4] prepared and published by the TMMi Foundation in 2012.

Figure 1 shows TMMi maturity levels and process areas and Figure 2 shows its structure and components. As the structure outlines, each maturity level has several process areas (PA), and each process area has several specific goals and specific practices. In total, under the four maturity levels (2, 3 and 4), the TMMi [4] specified 50 specific goals (SG) and 188 specific practices (SP). For example, under the level 2 (managed), there are five process areas, e.g., PA 2.1 (test policy and strategy). This PA has three SGs: SG 1-establish a test policy, SG 2-establish a test strategy, and SG 3-establish test performance indicators. The above SG 1, in turn, has three SPs: SP 1.1-define test goals, SP 1.2-define test policy, and SP 1.3-distribute the test policy to stakeholders.

1.2.2 Test Process Improvement (TPI)

TPI [5] and its newer version TPI-Next [9] have been developed by a Nederland-based company named Sogeti B.V. since 1998. The key areas of TPI are usually used as a basis for improving test processes. Slightly similar to TMMi, TPI differs from TMMi in that it is not maturity-level-based, but has a set of 16 key areas, e.g., test strategy, life-cycle model, and estimating and planning. Figure 3 shows TPI's structure and components. Each key area has two to four levels which are determined

during the assessment. For example, Table 2 shows two examples of TPI's maturity levels for two of the key areas.

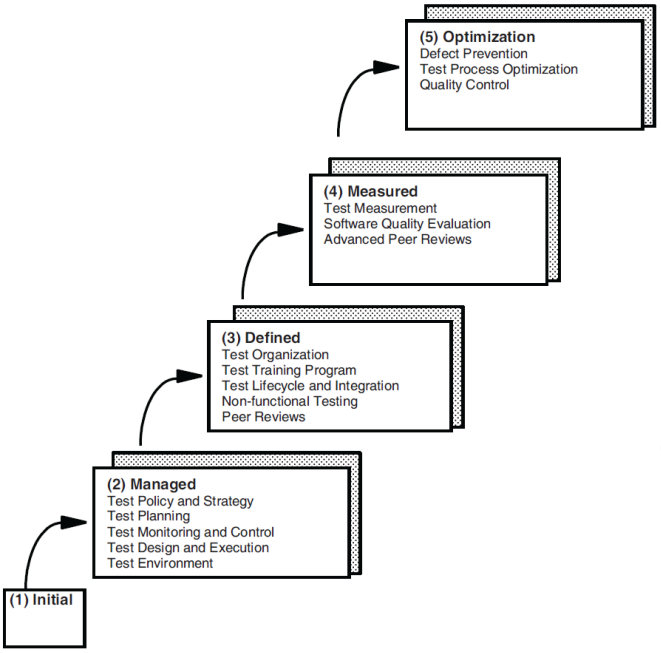

Figure 1 TMMi maturity levels and process areas [4]

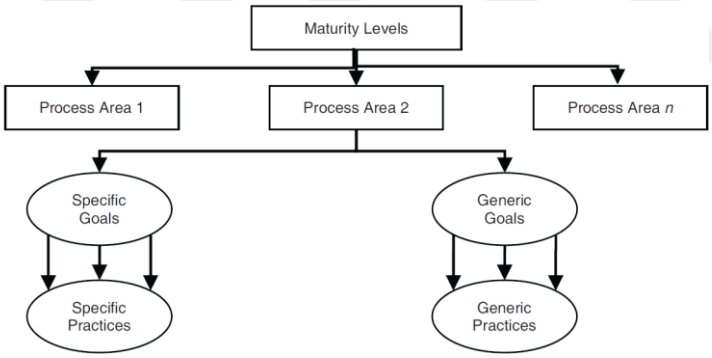

Figure 2 TMMi structure and components [4]

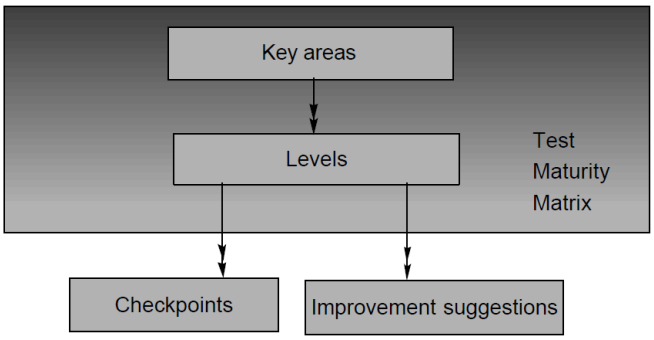

Figure 3 TPI structure and components [5]

Table 2 TPI's maturity levels and several example "key areas" of the model [5]

Key area		**Levels**			
#	**Name**	**A**	**B**	**C**	**D**
1	Test strategy	Strategy for single high-level test	Combined strategy for high-level	Combined strategy for high-level	Combined strategy for all test
2	Life-cycle model	Planning, specification, execution	Planning, preparation, specification, execution, completion		
3	Moment of involvement	Completion of test basis	Start of test basis	Start of requirements definition	Project initiation
4	Estimating and planning	Substantiated estimating and planning	Statistically substantiated estimating and		
20	Low-level testing	Low-level test lifecycle: planning, specification and execution	White-box techniques	Low-level test strategy	

1.3 Relevant Service Maturity Models

1.3.1 International Standards Organization / International Electrotechnical Commission (ISO/IEC) 20000

ISO/IEC 20000 [6] is an international standard for IT service management. The first version of this standard was designed ISO/IEC JTC1/SC7 in 2005. The next versions were developed in 2011 and 2012. This standard provides guidelines to design, deploy, deliver and improve services. In this way, service requirements are fulfilled. Various stakeholders can use ISO/IEC 20000-1:2011, e.g., organizations who want

to receive services from providers and need assurance whether their service requirements will be fulfilled.

ISO/IEC 20000 [6] has the following parts:

- 20000-1: Service management system requirements
- 20000-2: Guidance on the application of service management systems
- 20000-3: Service providers
- 20000-4: Process assessment model
- 20000-5: Exemplar implementation plan for ISO/IEC 20000-1
- 20000-6: Requirements for bodies providing audit and certification of service management systems. Currently being developed
- 20000-9: Guidance on the application of ISO/IEC 20000-1 to cloud services
- 20000-10: Concepts and terminology
- 20000-11: Guidance on the relationship between ISO/IEC 20000-1:2011 and service management frameworks: ITIL
- 20000-12: Guidance on the relationship between ISO/IEC 20000–1:2011 and service management frameworks: CMMI-SVC

As it can be seen above, parts #11 and 12 aim at establishing linkage and guidance between ISO/IEC 20000 and two other service management frameworks ITIL and CMMI-SVC (which I review next).

1.3.2 Information Technology Infrastructure Library (ITIL)

ITIL, an acronym for Information Technology Infrastructure Library [7]. ITIL provides a set of practices for aligning IT services and IT service management by the using business needs. In ITIL 2011 edition (current form), ITIL has a series of five core volumes. Each of that volumes covers a different stage of IT service management lifecycle. Although ITIL is used as a basis for ISO/IEC 20000, there are several differences between the two. Figure 4 shows the core areas of and components of ITIL.

Figure 4 Core areas of and components of ITIL [7]

1.3.3 Capability Maturity Model Integration for Services (CMMI-SVC)

CMMI for Services (CMMI-SVC) [2, 11] is a member of the CMMI family of maturity models (Capability Maturity Model Integration) [12]. CMMI is a process improvement training and appraisal program and service developed by Carnegie Mellon University (CMU). CMMI can be used to direct process improvement in a project or in a company. CMMI defines the following maturity levels for processes: (level 1): initial, (level 2) managed, (level 3) defined, (level 4) quantitatively managed, and (level 5) optimizing. Figure 5 shows the relationship among the CMMI family of maturity models. Apart from the base CMMI maturity model, the family has three sub-models: CMMI for Development (CMMI-DEV), CMMI for Services (CMMI-SVC), and CMMI for Acquisition (CMMI-ACQ).

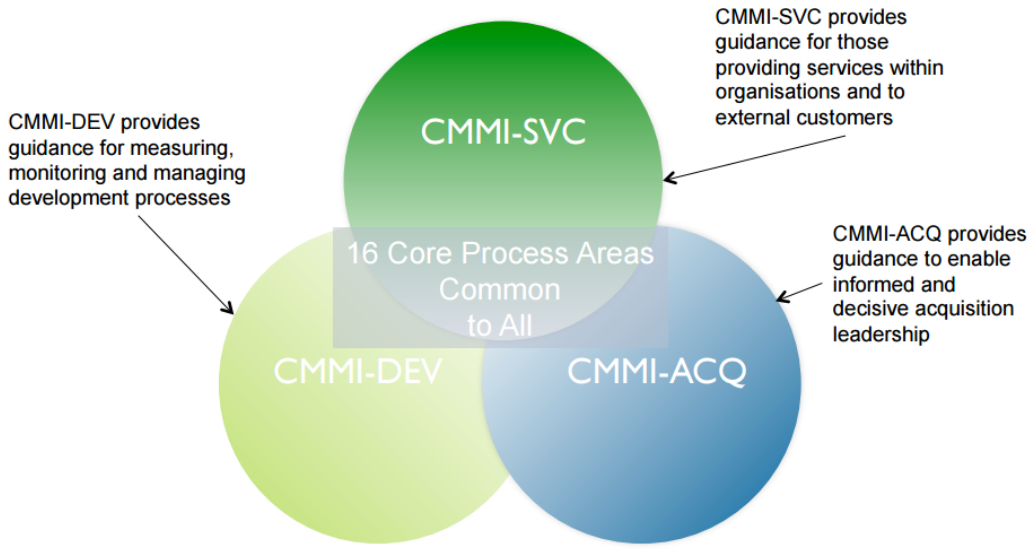

Figure 5 Relationship among the CMMI family of maturity models

Assistance on improving the quality of service practices is a major enabler for the performance of service provider and satisfaction of customers. The CMMI-SVC model is designed to meet that objective. The motto of CMMI-SVC is*: "Improving processes for providing better services".* Version 1.0 of CMMI-SVC was released on March 2009, and the version 1.3 was released on November 2010 [2].

Figure 6 shows the maturity levels and process areas (PAs) of CMMI-SVC. Each maturity levels contains several PAs. In the CMMI family of models, PA defined as collection of related practices in an area. When PA implemented collectively, it satisfies a set of specific goals that considered significant for making improvement in that area. The latest version of Capability Maturity Model Integration (CMMI), version 1.3, contains 22 PAs. The latest version of CMMI-SVC contains 24 PAs.

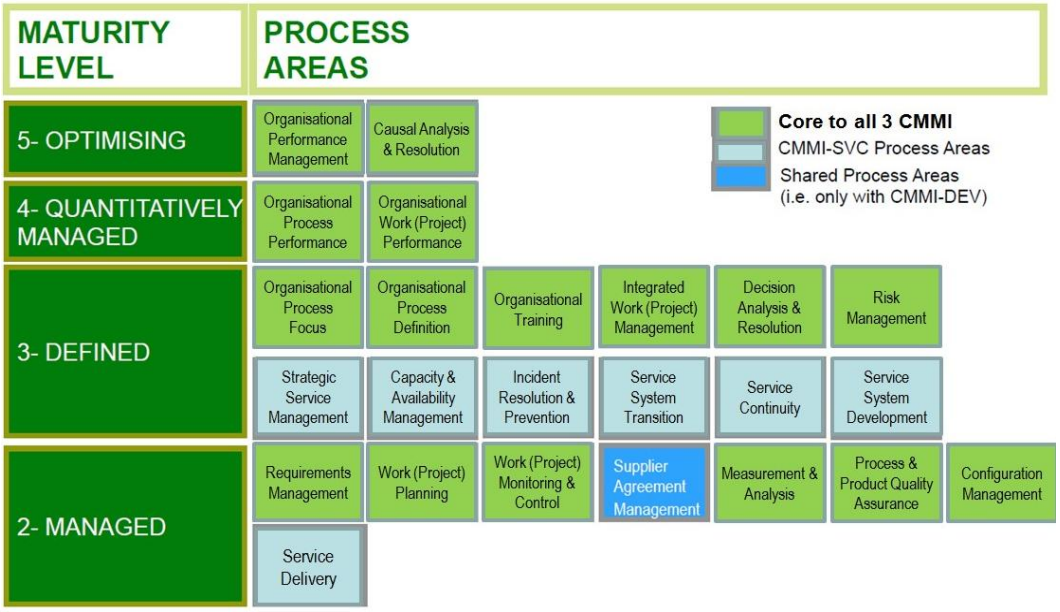

Figure 6 Maturity levels and process areas of CMMI for Services

A specific goal (SG) in CMMI explains the characteristics that must be fulfilled to satisfy a given process area. In this way, a SG is an item to be checked during assessments to ensure whether a process area is met by a team or company. A specific practice (SP) is the description of an activity that is seen important in achieving the corresponding specific goal.

Essentially, there are "aggregation" relationships between a PA and its underlying SGs, and a SG and its underlying SPs, as shown in Figure 7. For example, the PA (Service Delivery) in maturity level #2, includes 3 SGs and 8 SPs as shown below [2]:

- SG 1-Establish Service Agreements
    - SP 1.1 Analyze Existing Agreements and Service Data
    - SP 1.2 Establish the Service Agreement
- SG 2-Prepare for Service Delivery
    - SP 2.1 Establish the Service Delivery Approach
    - SP 2.2 Prepare for Service System Operations
    - SP 2.3 Establish a Request Management System
- SG 3-Deliver Services
    - SP 3.1 Receive and Process Service Requests
    - SP 3.2 Operate the Service System

- SP 3.3 Maintain the Service System

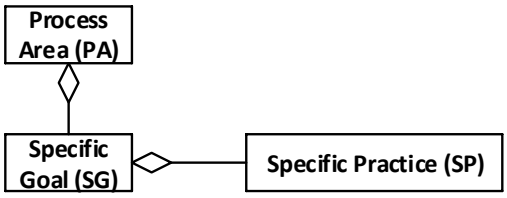

Figure 7 Relationship among Process Areas (PAs), Specific Goals (SGs) and Specific Practices (SPs) in the CMMI family of models

Out of the 24 PAs in CMMI-SVC, 16 are core process areas, 1 is a shared process area, and 7 are service-specific process areas. To review the list of the PAs under each of the maturity levels of CMMI-SVC, the reader can refer to the CMMI-SVC specifications [2].

1.3.4 Relationship Among The Different Models and Choosing A Base Model For This Work

Sources such as [13] have compared the relationship among the different models. The author of [13] reported that: "*CMMI-SVC provides almost complete coverage of ISO 20000 clauses*".

In terms of CMMI-SVC's advantages over ISO 20000, certain practices are not highlighted to the same extent in ISO20000, e.g., stakeholder management occurs in several locations in ISO 20000. However, it is an integrated part of every PA in CMMI-SVC, focusing on what users find important. Also, CMMI-SVC provides a more comprehensive set of practices for management of information, by providing practical measures to be identified and used, and also a structure for specifying and documenting information.

When comparing CMMI-SVC and ITIL, [13] reports that the structure and content of ITIL essentially looks like a "library", since it has five volumes, 1,342 pages in total, and it details "how to" implement service practices while CMMI-SVC details "what to" implement and provides a guideline of improvements.

In summary, [13] concludes that the three models (CMMI-SVC, ISO 20000 and ITIL) complement each other. While ITIL is a reference library full for this purpose, CMMI-SVC is the "reading list" for success, and ISO 20000 is the "exam". For this

reason, I decided to choose CMMI-SVC as the base model for this work, to build upon to develop the proposed maturity model for test services.

1.4 Need for Assessing Maturity of Software Testing Services

Although many test maturity models have been proposed, but as of this writing, no maturity model has been proposed for assessment of software testing 'services' and that is the goal of this work.

Based on an the principles of "action research" [19, 20], and a technology transfer model proposed by Gorschek et al. [21], as depicted in Figure 8, those motivations arose the need for the study and the model developed in this work. This work is also structured in the same manner, i.e., after identifying the need as reported in this sub-section, I reviewed the literature and then started the iterative development of the models which will be discussed in sequence in the rest of this work.

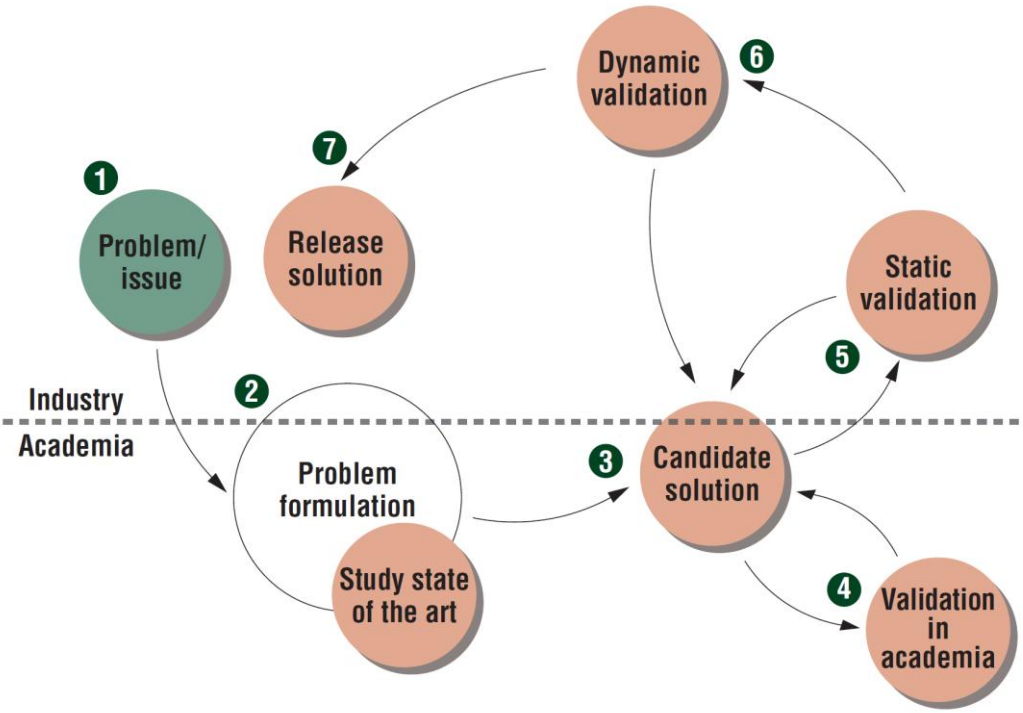

Figure 8 A model for technology transfer proposed by Gorschek et al. [21]. The concept is similar to the concept of "action research" [19, 20]

CHAPTER 2

A MATURITY MODEL FOR SOFTWARE TESTING SERVICES (MM-TSVC)

Before developing and proposing the models, the context has been reviewed and the process for establishment and delivery of test services in Sections 3.1 and 3.2. Then the model's development strategy has been discussed in Section 3.3. Then discussed an overall review of the model's structure and process areas in Section 3.4. Sections 3.5-3.8 then presented the details of the model, reviewing the details of the maturity levels #2…#5, in order.

2.1 Context for Establishment and Delivery of Test Services

To better understand the components, structure and process areas of MM-TSVC, it is important to clearly understand the context for establishment and delivery of services in general and test services in particular.

Adopted from the CMMI-SVC specifications [2], Figure 9 shows the key PA relationships for establishing and delivering services in CMMI-SVC. This diagram shows the inter-connection among the various PAs with the service customer (end user).

To understand the context for establishment and delivery of test services, I found the diagram Figure 9 too generic in some parts, lacking some other parts (e.g., the service provider actor), and also somewhat complex (having too many details). I thus adopted some ideas form it (e.g., the notion of service customer) and developed a revised/improved context diagram as shown in Figure 10.

This context diagram includes four actors: (1) customer (receiver of test services), (2) provider of test services, (3) sub-contractor for test services, and (4) supplier of test tools and products.

The primary entities are shown in the gray colour to show the central focal point in the context diagram.

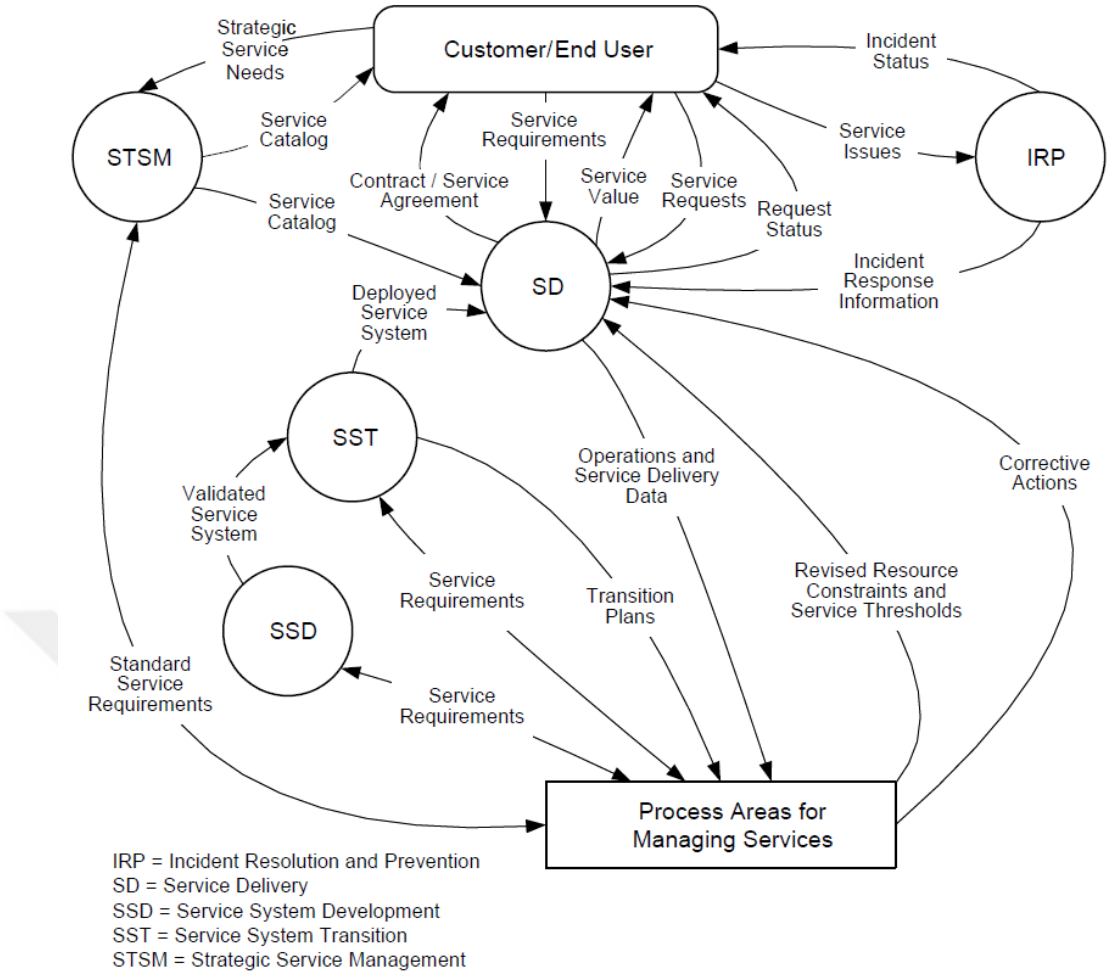

Figure 9 Key process area relationships for establishing and delivering services in CMMI-SVC [2]

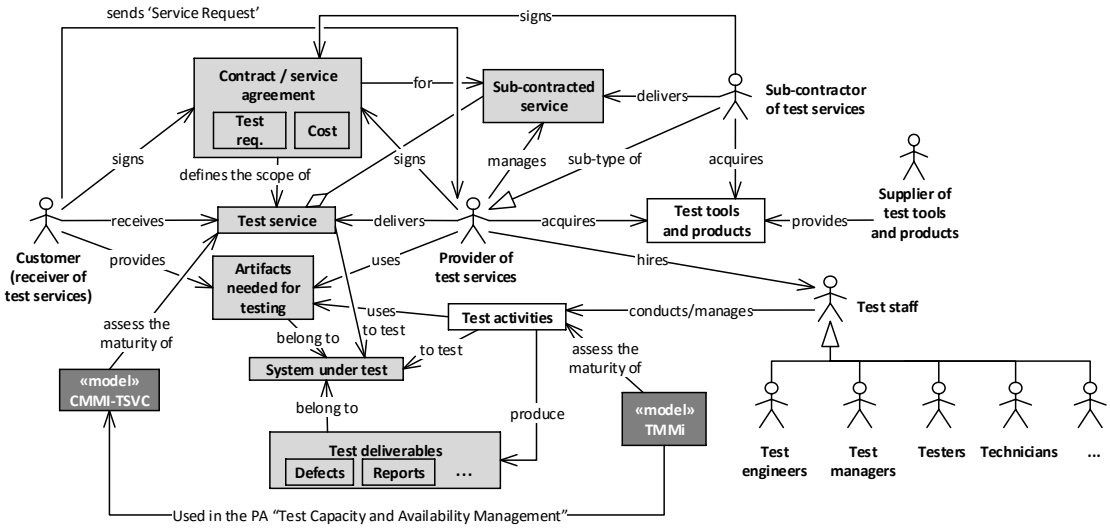

Figure 10 A UML context diagram for establishment and delivery of test services

2.2 Process for Establishment and Delivery of Test Services

Although the context for establishment and delivery of test services was depicted in Figure 10, to develop a high-quality maturity model for software testing services (MM-TSVC), there is also a need to understand and formalize the process for establishment and delivery of test services. By consultation with industry partners and using industry experience in offering test services, I have formalized that process as a UML activity diagram as shown in Figure 11.

Similar to Figure 10, there are two primary actors in this process: provider of test services, and customer (receiver of test services). A sub-contractor of test services is a type of provider as shown by the "sub-class" relationship in Figure 10 and Figure 11. When test services are contracted out, the sub-contractor "plays the role of" a provider and the intermediate service provider "plays the role of" customer (as a proxy).

The process starts the bidding and contracting phase which itself has these activities in order: Specify test service requirements, Request for bids, Submit bids (Bidding), Reviewing the bids, and Awarding the contract. Once the contract is in place, the planning and preparations starts. If a sub-contractor (or more) is (are) needed, a sub-process starts to conduct the bidding and contract job involving one or more sub-contractors.

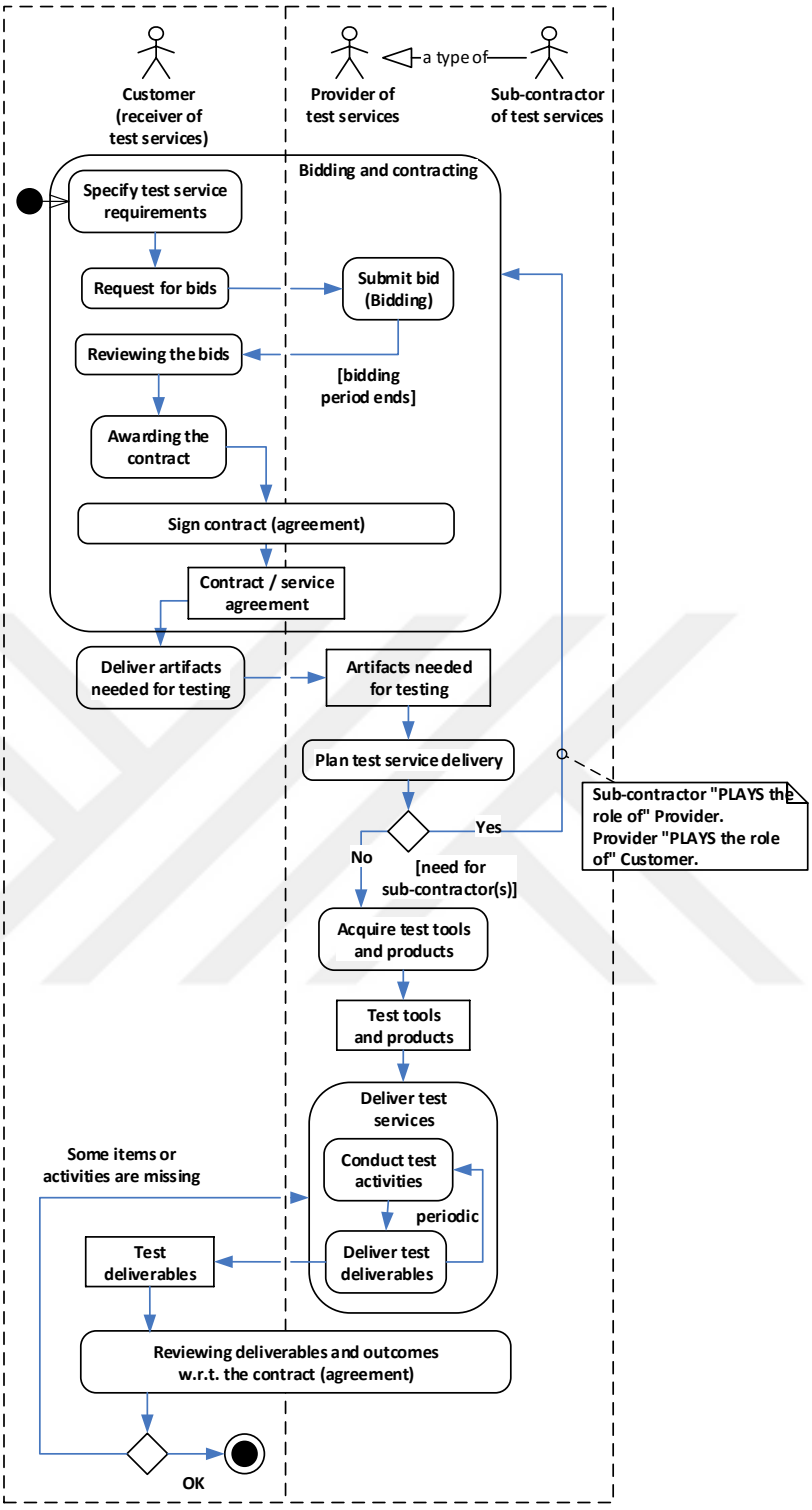

Figure 11 A UML activity diagram showing the process for establishment and delivery of test services

2.3 Model's Development Design and Strategy

In terms of the model's development strategy, I followed an iterative approach, i.e., I developed a first version and evolved it multiple times to meet the needs of the software testing industry. As discussed in Section 3.1, the need for developing a maturity model for assessing maturity of software testing services was based on real industrial needs.

In design and development of MM-TSVC, the author reviewed and benefitted from the general phases of maturity model development as outlines in a guideline paper [22] (shown in Figure 12). As shown, there are six phases involved in this process. The guidelines of [22] were carefully followed for conducting each phase, as reported next.

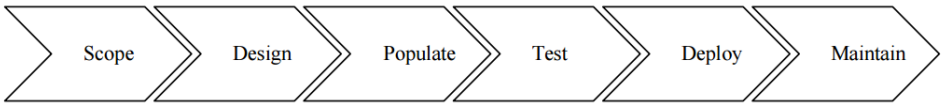

Figure 12 General development phases of maturity models [22]

For the first phase (scoping), [22] presents two dimensions to consider to decide upon (Table 3): focus of model and development stakeholders. How MM-TSVC is scoped w.r.t. (with respect to) these dimensions is underlined in Table 3. MM-TSVC is a domain specific models, and in its development, both academics and practitioners sources were utilized.

Table 3 Scoping of the MM-TSVC model

Criterion	**Characteristic**			
Focus of	Domain Specific		General	
Development	Academia	Practitioners	Government	Combinatio

The next phase of the development is the design phase (Figure 12) which has six criteria: audience, method of application, driver of application, respondents, and application. The choices made for these criteria have been highlighted in Table 4.

Table 4 Design details of the MM-TSVC model

Criterion	Characteristic		
Audience	Internal	External	
	Executives, Management	Auditors, Partners	
Method of	Self-assessment	Third party	Certified practitioner
Driver of Application	Internal requirement	External requirement	Both
Respondents	Management	Staff	Business partners
Application	1 entity / 1 region	Multiple entities / single region	Multiple entities / multiple regions

The next phase of the development is the 'populate' phase (Figure 12). Once the scope and design of the model are agreed, the content of the model must be decided. In this phase it is necessary to identify *what* needs to be measured in the maturity assessment and *how* this can be measured. Context diagram of Figure 13 shows that information, which was developed based on the examples provided in the guideline paper in [22]. The inter-relationship of the two models TMMi and MM-TSVC and how the application of the two would lead to business success of the stakeholders are shown here. As it can be seen, TMMi is more focused on the maturity assessment of technical test activities, e.g., use of proper test-case design methods, metrics and peer review, however MM-TSVC focuses on assessing and improving test services, tools and products, and processes.

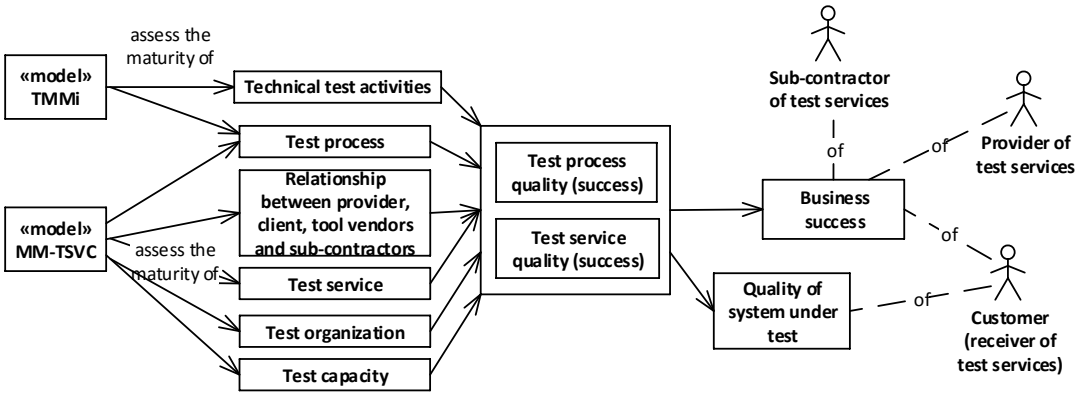

Figure 13 Context diagram for the 'populate' phase of the model development

From another viewpoint, the maturity model's development strategy was based on an the principles of "Action research" [19, 20] and a technology transfer model proposed by Gorschek et al. [21], as depicted in Figure 8, in which real industry needs drive the development of a needed model/approach. Thanks to strong

industrial connections and partnerships, the model was sent in several iterations to three expert (senior) test engineers and managers, working in three different software organizations in Turkey, and asked for their feedback during model's development phase. Their feedbacks were systematically solicited, collected and complied by applying qualitative coding [23].

Furthermore, in design and development of MM-TSVC, I reviewed and benefitted from two other sources: (1) an approach to assess design principles of maturity models [24], and (2) assessing maturity models' fit for purpose from users' perspective [25].

The work in [24] proposed a framework of design principles for what makes a useful maturity model. As shown in Table 5, the framework consists of nine principles under three categories: (1) basic design principles, (2) principles for prescriptive purpose of use, and (3) principles for descriptive purpose of use. I essentially ensured that I addressed each of the nine principles in my work, e.g., definition of constructs-maturity and maturation, to be discussed in the rest of this work.

Table 5 General design principles for maturity models [24]

Basic Design Principles	**1.1 Basic information**
	1.2 Definition of constructs-maturity and maturation
	1.3 Definition of constructs-application domain
	1.4 Target group-oriented documentation
Descriptive Purpose of Use	**2.1 Intersubjectively verifiable criteria for levels**
	2.2 Target group-oriented assessment methodology
Prescriptive Purpose of Use	**3.1 Improvement measures for each maturity level**
	3.2 Decision calculus for selecting improvement
	3.3 Target group-oriented decision methodology

Last but not the least, the work in [25] proposed (2) assessing maturity models' fit for purpose from users' perspective. The study argued that the literature of business process maturity models (BPMM) are mostly limited to the design perspective. The work in [25] introduced 14 criteria that potential BPMM users must consider to obtain useful models (Table 6).

Table 6 An overview of the 14 decision criteria for BPMM selection [25]

Assessment criteria	Improvement criteria	Non-design criteria
1. Availability	7. Architecture details	12. Costs
2. Data collection	8. Architecture type	13. Purpose
3. Duration	9. Capabilities	14. Validation
4. Nr. of questions	10. Nr. of processes	
5. Rating scale	11. Type of processes	
6. Respondents		

2.4 Structure and Process Areas

Since I have designed MM-TSVC based on the concept of CMMI-SVC and the CMMI family of models, I adopt the same structural concept which includes the notions of Process Areas (PAs), Specific Goals (SGs) and Specific Practices (SPs) as discussed in Section 2.1.3.

Figure 14 shows the maturity levels and process areas of MM-TSVC (top) and CMMI-SVC (below, for comparison purposes). As it can be seen, MM-TSVC adopts the CMMI-SVC models for the test services domain. Each and every PA has been customized to test services, e.g., Test Service Delivery in MM-TSVC versus Service Delivery in CMMI-SVC, or Test Service Agreement Management versus Supplier Agreement Management in CMMI-SVC. Inspired by the CMMI model, I have also added the maturity level #1 (initial) which is essentially ad-hoc (poorly controlled) service delivery. A few PAs have been revised quite a lot or are new in MM-TSVC compared to their CMMI-SVC counterparts. Such Pas have been underlined in Figure 14, e.g., Test Products and Sub-Contract Services Management in MM-TSVC versus Supplier Agreement Management in CMMI-SVC, the rationale of which will be discussed in the next sub-sections.

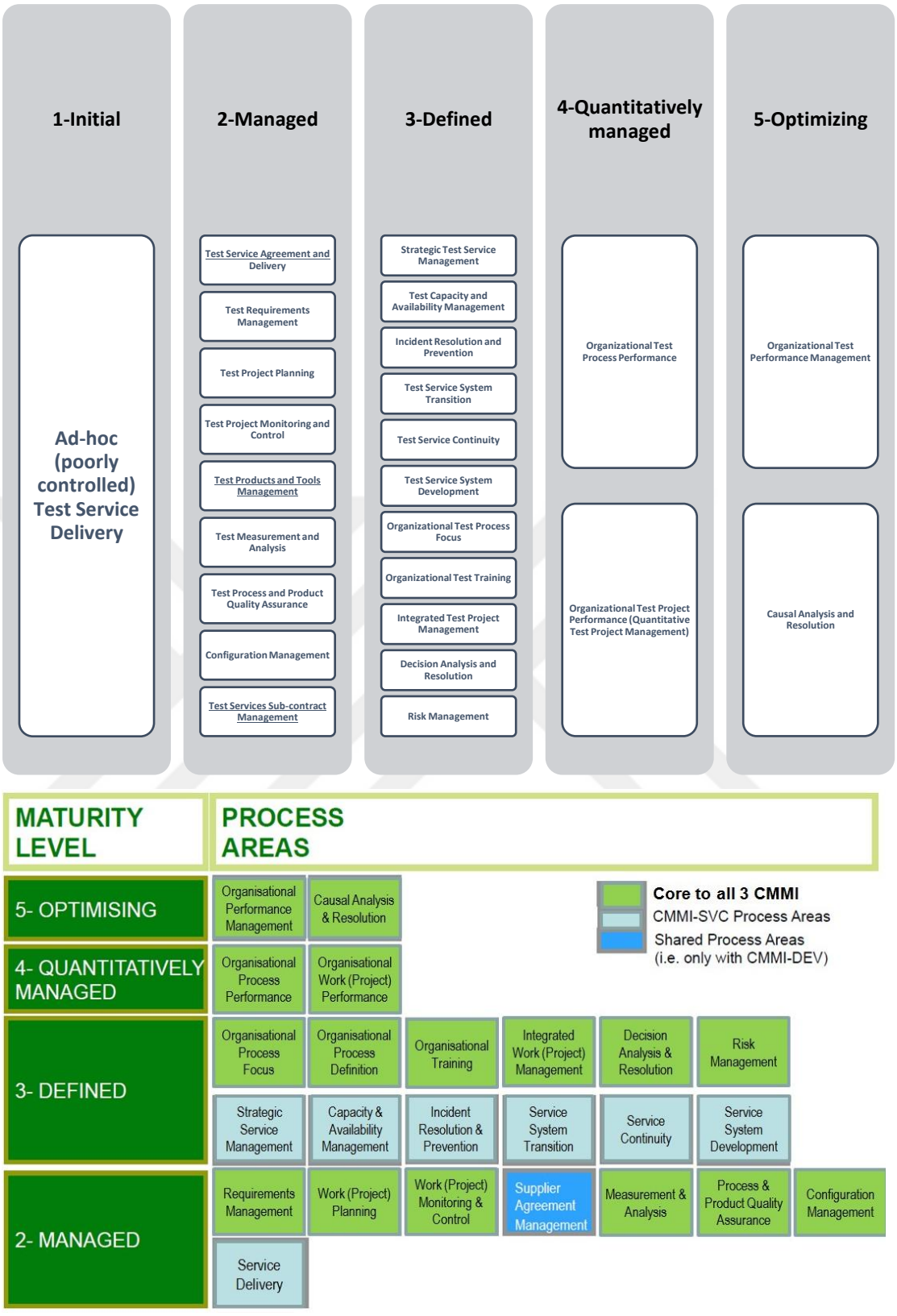

Figure 14 Process areas of MM-TSVC (top) and CMMI-SVC (below, for comparison purposes)

Classified below by the maturity levels, the Specific Goals (SGs) and Specific Practices (SPs) of each PA are discussed.

As discussed above, level #1 is the ‘initial’ level in which service delivery is essentially ad-hoc (poorly controlled). There are no PAs in this level. The comparison of SGs and SPs of each PA proposed in this study and their CMMI-SVC equivalents [2] in level 2 were given in Tables 7-14. Comparison tables regarding level 3, level 4 and level 5 were given in Tables 15-25 Tables 26-27 and Tables 28-29, respectively.

Table 7 Test Service Agreement Establishment And Delivery

<table>
<tr><td>PA name in MM-TSVC:</td><td>Test service agreement establishment and delivery</td><td>PA name in CMMI-SVC:</td><td>Service Delivery</td></tr>
<tr><td>Purpose in MM-TSVC:</td><td>Deliver test services in accordance with test service agreements put in place in the contract.</td><td>Purpose in CMMI-SVC:</td><td>Deliver services in accordance with service agreements.</td></tr>
<tr><td colspan="2">• SG 1 Establish Service Agreements
o SP 1.1 Analyze test service and customer needs
o SP 1.2 Discus and negotiate elements of the Test Service Agreement (contract), e.g., basic details such as test requirements, duration/cost, and other issues that I have heard from the industry partners such as regression tests and when to stop testing
o SP 1.3 Establish the test Service Agreement (contract)
• SG 2 Prepare for Service Delivery
o SP 2.1 Establish the Test Service Delivery Approach
o SP 2.2 Prepare for Test Service Operations (mostly internal to the test team)
• SG 3 Deliver Services
o SP 3.1 Receive and Process Service Requests
o SP 3.2 Operate the Service System (including test staff, test processes and test activities)
o SP 3.3 Maintain the Test Service System (including test staff, test processes and test activities)</td><td colspan="2">• SG 1 Establish Service Agreements
o SP 1.1 Analyze Existing Agreements and Service Data
o SP 1.2 Establish the Service Agreement
• SG 2 Prepare for Service Delivery
o SP 2.1 Establish the Service Delivery Approach
o SP 2.2 Prepare for Service System Operations
o SP 2.3 Establish a Request Management System
• SG 3 Deliver Services
o SP 3.1 Receive and Process Service Requests
o SP 3.2 Operate the Service System
o SP 3.3 Maintain the Service System</td></tr>
<tr><td colspan="4">Note: The PA name in CMMI-SVC is Service Delivery. However, to be more precise and as it can be seen from the list of SGs (below), it was rephrased to ‘Test Service Agreement and Delivery’ in MM-TSVC. The PA includes both service agreement and service delivery.</td></tr>
</table>

Table 8 Test Requirements Management

PA name in MM-TSVC:	Test requirements management	PA name in CMMI-SVC:	Requirements Management
Purpose in MM-TSVC:	Manage requirements of test services to be done and to ensure alignment between those requirements and the test plans and activities.	Purpose in CMMI-SVC:	Manage requirements of products and product components and to ensure alignment between those requirements and the work plans and work products.
• SG 1 Manage Test Requirements ○ SP 1.1 Understand Test Requirements as documented in the Test Service Agreement (contract) ○ SP 1.2 Manage Test Requirements Changes ○ SP 1.3 Maintain Bidirectional Traceability of Requirements to Tests and other artifacts (if any) ○ SP 1.5 Ensure Alignment Between Work Products (Test Deliverables), Test Activities and Test Requirements		• SG 1 Manage Requirements ○ SP 1.1 Understand Requirements ○ SP 1.2 Obtain Commitment to Requirements ○ SP 1.3 Manage Requirements Changes ○ SP 1.4 Maintain Bidirectional Traceability of Requirements ○ SP 1.5 Ensure Alignment Between Work Products and Requirements	

Table 9 Test Project Planning

PA name in MM-TSVC:	Test project planning	PA name in CMMI-SVC:	Work (Project) Planning
Purpose in MM-TSVC:	Establish and maintain plans (major tasks, estimates, risks and resources) for the test service project.	Purpose in CMMI-SVC:	Establish and maintain plans (major tasks, estimates, risks and resources) for service work.

• SG 1 Establish Estimates
  ○ SP 1.1 Establish the Strategy for the Test Service
  ○ SP 1.2 Estimate the Scope of the Work
  ○ SP 1.3 Establish Estimates of Work Product and Task Attributes
  ○ SP 1.4 Define Lifecycle Phases
  ○ SP 1.5 Estimate Effort and Cost
• SG 2 Develop a Work Plan
  ○ SP 2.1 Establish the Budget and Schedule
  ○ SP 2.2 Identify Risks
  ○ SP 2.3 Plan Test Data Management
  ○ SP 2.4 Plan the Resources
  ○ SP 2.5 Plan the Needed Knowledge and Skills
  ○ SP 2.6 Plan Stakeholder Involvement
  ○ SP 2.7 Establish the Work Plan (using Work breakdown structure, WBS)
• SG 3 Obtain Commitment to the Plan
  ○ SP 3.1 Review all plans that affect the work to understand work commitments
  ○ SP 3.2 Adjust the work plan to reconcile available and estimated resources
  ○ SP 3.3 Obtain Plan Commitment from Stakeholders
		• SG 1 Establish Estimates
		  ○ SP 1.1 Establish the Service Strategy
		  ○ SP 1.2 Estimate the Scope of the Work
		  ○ SP 1.3 Establish Estimates of Work Product and Task Attributes
		  ○ SP 1.4 Define Lifecycle Phases
		  ○ SP 1.5 Estimate Effort and Cost
		• SG 2 Develop a Work Plan
		  ○ SP 2.1 Establish the Budget and Schedule
		  ○ SP 2.2 Identify Risks
		  ○ SP 2.3 Plan Data Management
		  ○ SP 2.4 Plan the Resources
		  ○ SP 2.5 Plan Needed Knowledge and Skills
		  ○ SP 2.6 Plan Stakeholder Involvement
		  ○ SP 2.7 Establish the Work Plan
		• SG 3 Obtain Commitment to the Plan
		  ○ SP 3.1 Review Plans That Affect the Work
		  ○ SP 3.2 Reconcile Work and Resource Levels
		  ○ SP 3.3 Obtain Plan Commitment	

Table 10 Test Project Monitoring and Control

PA name in MM-TSVC:	Test Project Monitoring and Control	PA name in CMMI-SVC:	Work (Project) Monitoring and Control
Purpose in MM-TSVC:	Monitoring the project and service's progress so that appropriate corrective actions can be taken when performance deviates significantly from the plan.	Purpose in CMMI-SVC:	Understand the work's progress so that appropriate corrective actions can be taken when performance deviates significantly from the plan.

• SG 1 Continuously/periodically Monitor the Work Progress Against the Plan
  ○ SP 1.1 Monitor Work Planning Parameters (work products and tasks, costs, effort, and schedule)
  ○ SP 1.2 Monitor Stakeholder Commitments
  ○ SP 1.3 Monitor Risks
  ○ SP 1.4 Monitor Data Management
  ○ SP 1.5 Monitor Stakeholder Involvement
  ○ SP 1.6 Conduct Progress Reviews
  ○ SP 1.7 Conduct Milestone Reviews
• SG 2 Manage Corrective Action to Closure
  ○ SP 2.1 Analyze Issues
  ○ SP 2.2 Take Corrective Action
  ○ SP 2.3 Manage Corrective Actions
		• SG 1 Monitor the Work Against the Plan
		  ○ SP 1.1 Monitor Work Planning Parameters
		  ○ SP 1.2 Monitor Commitments
		  ○ SP 1.3 Monitor Risks
		  ○ SP 1.4 Monitor Data Management
		  ○ SP 1.5 Monitor Stakeholder Involvement
		  ○ SP 1.6 Conduct Progress Reviews
		  ○ SP 1.7 Conduct Milestone Reviews
		• SG 2 Manage Corrective Action to Closure
		  ○ SP 2.1 Analyze Issues
		  ○ SP 2.2 Take Corrective Action
		  ○ SP 2.3 Manage Corrective Actions	

Table 11 Test Products (Tools) And Sub-Contract Management

<table>
<tr><td>PA name in MM-TSVC:</td><td>Test products (tools) and sub-contract management</td><td>PA name in CMMI-SVC:</td><td>Supplier Agreement Management</td></tr>
<tr><td>Purpose in MM-TSVC:</td><td>Manage the acquisition of products and sub-contract services from suppliers.</td><td>Purpose in CMMI-SVC:</td><td>Manage the acquisition of products and services from suppliers.</td></tr>
<tr><td colspan="2">• SG 1 Establish Supplier Agreements for both test products (tools) and services to be sub-contracted
  ○ SP 1.1 Determine Acquisition Type
  ○ SP 1.2 Select Suppliers
  ○ SP 1.3 Establish Supplier Agreements
• SG 2 Manage test products (tools)
  ○ SP 2.1 Acquire, install and use test products (tools)
  ○ SP 2.2 Maintain (update. get support for) test products (tools)
• SG 3 Manage sub-contracted services
  ○ SP 3.1 Monitor sub-contracted services
  ○ SP 3.2 Accept the sub-contracted services
  ○ SP 3.3 Ensure Transition of services from sub-contractor to client</td><td colspan="2">• SG 1 Establish Supplier Agreements
  ○ SP 1.1 Determine Acquisition Type
  ○ SP 1.2 Select Suppliers
  ○ SP 1.3 Establish Supplier Agreements
• SG 2 Satisfy Supplier Agreements
  ○ SP 2.1 Execute the Supplier Agreement
  ○ SP 2.2 Accept the Acquired Product
  ○ SP 2.3 Ensure Transition of Products</td></tr>
<tr><td colspan="4">Note: Sub-contracting of Software Services are quite common, e.g., see the experience report in [26].</td></tr>
</table>

Table 12 Measurement And Analysis for Test Service Management

PA name in MM-TSVC:	Measurement and analysis for test service management	PA name in CMMI-SVC:	Measurement and Analysis
Purpose in MM-TSVC:	Develop and sustain a measurement capability that is used to support management information needs	Purpose in CMMI-SVC:	Develop and sustain a measurement capability that is used to support management information needs.

• SG 1 Align test Measurement and Analysis Activities
  ○ SP 1.1 Establish test Measurement Objectives
  ○ SP 1.2 Specify test metrics (examples: test service schedule, cost and quality metrics)
  ○ SP 1.3 Specify Data Collection and Storage Procedures
  ○ SP 1.4 Specify Analysis Procedures
• SG 2 Provide Measurement Results
  ○ SP 2.1 Obtain Measurement Data
  ○ SP 2.2 Analyze Measurement Data
  ○ SP 2.3 Store Data and Results
  ○ SP 2.4 Communicate Results to stakeholders
		• SG 1 Align Measurement and Analysis Activities
		  ○ SP 1.1 Establish Measurement Objectives
		  ○ SP 1.2 Specify Measures
		  ○ SP 1.3 Specify Data Collection and Storage Procedures
		  ○ SP 1.4 Specify Analysis Procedures
		• SG 2 Provide Measurement Results
		  ○ SP 2.1 Obtain Measurement Data
		  ○ SP 2.2 Analyze Measurement Data
		  ○ SP 2.3 Store Data and Results
		  ○ SP 2.4 Communicate Results	

Table 13 Test Process And Product Quality Assurance

PA name in MM-TSVC:	Test process and product quality assurance	PA name in CMMI-SVC:	Process and Product Quality Assurance
Purpose in MM-TSVC:	Provide staff and management with objective insight into test processes and associated work products.	Purpose in CMMI-SVC:	Provide staff and management with objective insight into processes and associated work products.

• SG 1 Objectively Evaluate test Processes and Work Products
  ○ SP 1.1 Objectively Evaluate Processes
  ○ SP 1.2 Objectively Evaluate Work Products (test deliverables such as defects, test reports, etc.)
• SG 2 Provide Objective Insight
  ○ SP 2.1 Communicate and Resolve Noncompliance Issues
  ○ SP 2.2 Establish Records
		• SG 1 Objectively Evaluate Processes and Work Products
		  ○ SP 1.1 Objectively Evaluate Processes
		  ○ SP 1.2 Objectively Evaluate Work Products
		• SG 2 Provide Objective Insight
		  ○ SP 2.1 Communicate and Resolve Noncompliance Issues
		  ○ SP 2.2 Establish Records	

Table 14 Configuration Management

PA name in MM-TSVC:	Configuration management	PA name in CMMI-SVC:	Configuration Management
Purpose in MM-TSVC:	Establish and maintain the integrity of work products using configuration identification, configuration control, configuration status accounting, and configuration audits.	Purpose in CMMI-SVC:	Establish and maintain the integrity of work products. For this purpose Identification, configuration, configuration, control, configuration status accounting, and configuration audits are used.

• SG 1 Establish Baselines (versions)
  ○ SP 1.1 Identify Configuration Items (e.g., any work product)
  ○ SP 1.2 Establish a Configuration Management System
  ○ SP 1.3 Create or Release Baselines (versions)
• SG 2 Track and Control Changes
  ○ SP 2.1 Track Change Requests
  ○ SP 2.2 Control Configuration Items
• SG 3 Establish Integrity
  ○ SP 3.1 Establish Configuration Management Records
  ○ SP 3.2 Perform Configuration Audits
		• SG 1 Establish Baselines
		  ○ SP 1.1 Identify Configuration Items
		  ○ SP 1.2 Establish a Configuration Management System
		  ○ SP 1.3 Create or Release Baselines
		• SG 2 Track and Control Changes
		  ○ SP 2.1 Track Change Requests
		  ○ SP 2.2 Control Configuration Items
		• SG 3 Establish Integrity
		  ○ SP 3.1 Establish Configuration Management Records
		  ○ SP 3.2 Perform Configuration Audits	

Table 15 Strategic Test Service Management

PA name in MM-TSVC:	Strategic test service management	PA name in CMMI-SVC:	Strategic service management
Purpose in MM-TSVC:	Establish and maintain standard test services in concert with strategic needs and plans.	Purpose in CMMI-SVC:	Establish and maintain standard services in concert with strategic needs and plans.

• SG 1 Establish Strategic Needs and Plans for Standard Services
  ○ SP 1.1 Gather and Analyze Data
  ○ SP 1.2 Establish Plans for Standard Services
• SG 2 Establish Standard Services
  ○ SP 2.1 Establish Properties of Standard Services and Service Levels
  ○ SP 2.2 Establish Descriptions of Standard Services
		• SG 1 Establish Strategic Needs and Plans for Standard Services
		  ○ SP 1.1 Gather and Analyze Data
		  ○ SP 1.2 Establish Plans for Standard Services
		• SG 2 Establish Standard Services
		  ○ SP 2.1 Establish Properties of Standard Services and Service Levels
		  ○ SP 2.2 Establish Descriptions of Standard Services	

Table 16 Test Capacity And Availability Management

<table>
<tr><td>PA name in MM-TSVC:</td><td>Test Capacity and Availability Management</td><td>PA name in CMMI-SVC:</td><td>Capacity and Availability Management</td></tr>
<tr><td>Purpose in MM-TSVC:</td><td>The purpose is to ensure effective test service system performance and ensure that resources are provided and used effectively to support test service requirements.</td><td>Purpose in CMMI-SVC:</td><td>The purpose is to ensure effective service system performance and ensure that resources are provided and used effectively to support service requirements.</td></tr>
<tr><td colspan="2">• SG 1 Prepare for test Capacity and Availability Management
o SP 1.1 Establish a test Capacity and Availability Management Strategy (most probably, the best choice of strategy for test capacity and maturity assessment will be to use the TMMi [4])
o SP 1.2 Select test Measures (metrics) and Analytic Techniques
o SP 1.3 Establish test Service System Representations (this may include test process simulation and system dynamics, e.g., [27-29])
• SG 2 Monitor and Analyze test Capacity and Availability
o SP 2.1 Monitor and Analyze test capacity
o SP 2.2 Monitor and Analyze test service Availability
o SP 2.3 Report test Capacity and Availability Management Data</td><td colspan="2">• SG 1 Prepare for Capacity and Availability Management
o SP 1.1 Establish a Capacity and Availability Management Strategy
o SP 1.2 Select Measures and Analytic Techniques
o SP 1.3 Establish Service System Representations
• SG 2 Monitor and Analyze Capacity and Availability
o SP 2.1 Monitor and Analyze Capacity
o SP 2.2 Monitor and Analyze Availability
o SP 2.3 Report Capacity and Availability Management Data</td></tr>
<tr><td colspan="4">Note: “Capacity” in this context is the degree to which the service provider can support and/or provide test services. In the context of test services, capacity can refer to the extent of test service delivery or maximum number of service requests that a service provider can handle successfully with the specified quality within a fixed period of time.</td></tr>
</table>

Table 17 Incident Resolution And Prevention

PA name in MM-TSVC:	Incident resolution and prevention	PA name in CMMI-SVC:	Incident resolution and prevention
Purpose in MM-TSVC:	The purpose is to ensure timely and effective resolution of test service incidents and prevention of test service incidents as appropriate.	Purpose in CMMI-SVC:	The purpose is to ensure timely and effective resolution of service incidents and prevention of service incidents as appropriate.

• SG 1 Prepare for Incident Resolution and Prevention
  ○ SP 1.1 Establish an Approach to Incident Resolution and Prevention
  ○ SP 1.2 Establish an Incident Management System
• SG 2 Identify, Control, and Address Individual Incidents
  ○ SP 2.1 Identify and Record Incidents
  ○ SP 2.2 Analyze Individual Incident Data
  ○ SP 2.3 Resolve Incidents
  ○ SP 2.4 Monitor the Status of Incidents to Closure
  ○ SP 2.5 Communicate the Status of Incidents
• SG 3 Analyze and Address Causes and Impacts of Selected Incidents
  ○ SP 3.1 Analyze Selected Incidents
  ○ SP 3.2 Establish Solutions to Respond to Future Incidents
• SP 3.3 Establish and Apply Solutions to Reduce Incident Occurrence
		• SG 1 Prepare for Incident Resolution and Prevention
		  ○ SP 1.1 Establish an Approach to Incident Resolution and Prevention
		  ○ SP 1.2 Establish an Incident Management System
		• SG 2 Identify, Control, and Address Individual Incidents
		  ○ SP 2.1 Identify and Record Incidents
		  ○ SP 2.2 Analyze Individual Incident Data
		  ○ SP 2.3 Resolve Incidents
		  ○ SP 2.4 Monitor the Status of Incidents to Closure
		  ○ SP 2.5 Communicate the Status of Incidents
		• SG 3 Analyze and Address Causes and Impacts of Selected Incidents
		  ○ SP 3.1 Analyze Selected Incidents
		  ○ SP 3.2 Establish Solutions to Respond to Future Incidents
		  ○ SP 3.3 Establish and Apply Solutions to Reduce Incident Occurrence	

Table 18 Test Service System Transition

PA name in MM-TSVC:	Test service system transition	PA name in CMMI-SVC:	Service System Transition
Purpose in MM-TSVC:	The purpose is to deploy new or significantly changed test service system components (e.g., sub-contractors, test engineers, test tools) while managing their effect on ongoing test service delivery. This may include replacing the sub-contractors, test engineers, test tools and test practices used in a current service project.	Purpose in CMMI-SVC:	The purpose is to deploy new or significantly changed service system components while managing their effect on ongoing service delivery.

• SG 1 Prepare for test Service System Transition
  ○ SP 1.1 Analyze test Service System Transition Needs
  ○ SP 1.2 Develop test Service System Transition Plans
  ○ SP 1.3 Prepare Stakeholders for Changes
• SG 2 Deploy the test Service System
  ○ SP 2.1 Deploy Service System Components
  ○ SP 2.2 Assess and Control the Impacts of the Transition
		• SG 1 Prepare for Service System Transition
		  ○ SP 1.1 Analyze Service System Transition Needs
		  ○ SP 1.2 Develop Service System Transition Plans
		  ○ SP 1.3 Prepare Stakeholders for Changes
		• SG 2 Deploy the Service System
		  ○ SP 2.1 Deploy Service System Components
		  ○ SP 2.2 Assess and Control the Impacts of the Transition	

Table 19 Test Service Continuity

PA name in MM-TSVC:	Test service continuity	PA name in CMMI-SVC:	Service Continuity
Purpose in MM-TSVC:	The purpose is to establish and maintain plans to ensure continuity of test services during and following any significant disruption of normal operations.	Purpose in CMMI-SVC:	The purpose is to establish and maintain plans to ensure continuity of services during and following any significant disruption of normal operations.

• SG 1 Identify Essential Service Dependencies
  ○ SP 1.1 Identify and Prioritize Essential Functions
  ○ SP 1.2 Identify and Prioritize Essential Resources
• SG 2 Prepare for Service Continuity
  ○ SP 2.1 Establish Service Continuity Plans
  ○ SP 2.2 Establish Service Continuity Training
  ○ SP 2.3 Provide and Evaluate Service Continuity Training
• SG 3 Verify and Validate the Service Continuity Plan
  ○ SP 3.1 Prepare for the Verification and Validation of the Service Continuity Plan
  ○ SP 3.2 Verify and Validate the Service Continuity Plan
  ○ SP 3.3 Analyze Results of Verification and Validation of the Service Continuity Plan
		• SG 1 Identify Essential Service Dependencies
		  ○ SP 1.1 Identify and Prioritize Essential Functions
		  ○ SP 1.2 Identify and Prioritize Essential Resources
		• SG 2 Prepare for Service Continuity
		  ○ SP 2.1 Establish Service Continuity Plans
		  ○ SP 2.2 Establish Service Continuity Training
		  ○ SP 2.3 Provide and Evaluate Service Continuity Training
		• SG 3 Verify and Validate the Service Continuity Plan
		  ○ SP 3.1 Prepare for the Verification and Validation of the Service Continuity Plan
		  ○ SP 3.2 Verify and Validate the Service Continuity Plan
		  ○ SP 3.3 Analyze Results of Verification and Validation of the Service Continuity Plan	

Table 20 Test Service System Development

PA name in MM-TSVC:	Test service system development	PA name in CMMI-SVC:	Service System Development
Purpose in MM-TSVC:	The purpose is to analyze, design, develop, integrate, verify, and validate test service systems, including service system components, to satisfy existing or anticipated service agreements.	Purpose in CMMI-SVC:	Analyze, design, develop, integrate, verify, and validate service systems. This includes service system components.

• SG 1 Prepare for test service system transition
  ○ SP 1.1 Analyze service system transition needs
  ○ SP 1.2 Develop service system transition plans
  ○ SP 1.3 Prepare stakeholders for changes
• SG 2 Deploy the Service System
  ○ SP 2.1 Deploy service system components
  ○ SP 2.2 Assess and control the impacts of the transition
		• SG 1 Prepare for Service System Transition
		  ○ SP 1.1 Analyze service system transition needs
		  ○ SP 1.2 Develop service system transition plans
		  ○ SP 1.3 Prepare stakeholders for changes
		• SG 2 Deploy the Service System
		  ○ SP 2.1 Deploy service system components
		  ○ SP 2.2 Assess and control the impacts of the transition	

Table 21 Organizational Test Process Focus (Improvement)

PA name in MM-TSVC:	Organizational test process focus (improvement)	PA name in CMMI-SVC:	Organizational Process Focus
Purpose in MM-TSVC:	The purpose is to plan, implement, and deploy organizational test process improvements based on a thorough understanding of current strengths and weaknesses of the organization's test processes and process assets. Test process improvement (TPI) activities will likely use test maturity assessment and test process improvement models discussed in Section 2.1.	Purpose in CMMI-SVC:	Plan, implement, and deploy organizational process improvements. These activities are done based on a thorough understanding of current strengths and weaknesses of the organization.

• SG 1 Determine test process improvement opportunities
  ○ SP 1.1 Establish organizational process needs
  ○ SP 1.2 Appraise the organization's processes
  ○ SP 1.3 Identify the Organization's test Process Improvements
• SG 2 Plan and implement test process actions
  ○ SP 2.1 Establish process action plans
  ○ SP 2.2 Implement process action plans
• SG 3 Deploy Organizational test process assets and incorporate experiences
  ○ SP 3.1 Deploy organizational process assets
  ○ SP 3.2 Deploy standard processes
  ○ SP 3.3 Monitor the implementation
  ○ SP 3.4 Incorporate experiences into organizational process assets
		• SG 1 Determine process improvement opportunities
		  ○ SP 1.1 Establish organizational process needs
		  ○ SP 1.2 Appraise the organization's processes
		  ○ SP 1.3 Identify the Organization's Process Improvements
		• SG 2 Plan and implement process actions
		  ○ SP 2.1 Establish process action plans
		  ○ SP 2.2 Implement process action plans
		• SG 3 Deploy organizational process assets and incorporate experiences
		  ○ SP 3.1 Deploy organizational process assets
		  ○ SP 3.2 Deploy standard processes
		  ○ SP 3.3 Monitor the implementation
		  ○ SP 3.4 Incorporate experiences into organizational process assets	

Table 22 Organizational Test Training

PA name in MM-TSVC:	Organizational test training	PA name in CMMI-SVC:	Organizational Training
Purpose in MM-TSVC:	The purpose is to develop skills and knowledge of people (testers and test engineers) so they can perform their roles effectively and efficiently.	Purpose in CMMI-SVC:	The purpose is to develop skills and knowledge of people so they can perform their roles effectively and efficiently.

• SG 1 Establish an Organizational test Training Capability
  ○ SP 1.1 Establish strategic test training needs
  ○ SP 1.2 Determine which test training needs are the responsibility of the organization
  ○ SP 1.3 Establish an organizational training tactical plan
  ○ SP 1.4 Establish a training capability
• SG 2 Provide Training
  ○ SP 2.1 Deliver training
  ○ SP 2.2 Establish training records
  ○ SP 2.3 Assess training effectiveness
		• SG 1 Establish an Organizational Training Capability
		  ○ SP 1.1 Establish strategic training needs
		  ○ SP 1.2 Determine which training needs are the responsibility of the organization
		  ○ SP 1.3 Establish an organizational training tactical plan
		  ○ SP 1.4 Establish a training capability
		• SG 2 Provide Training
		  ○ SP 2.1 Deliver training
		  ○ SP 2.2 Establish training records
		  ○ SP 2.3 Assess training effectiveness	

Table 23 Integrated Test Project Management

PA name in MM-TSVC:	Integrated test project management	PA name in CMMI-SVC:	Integrated work (project) management
Purpose in MM-TSVC:	The purpose is to establish and manage the test work (activities) and the involvement of relevant stakeholders according to an integrated and defined process that is tailored from the organization's set of standard processes.	Purpose in CMMI-SVC:	Establish and manage the work and the involvement of relevant stakeholders. This is done according to an integrated and defined process.

• SG 1 Use the defined test process for the work
  ○ SP 1.1 Establish the defined test process
  ○ SP 1.2 Use organizational test process assets for planning work activities
  ○ SP 1.3 Establish the test work environment
  ○ SP 1.4 Integrate plans
  ○ SP 1.5 Manage the work using integrated plans
  ○ SP 1.6 Establish test teams
  ○ SP 1.7 Contribute to organizational process assets
• SG 2 Coordinate and collaborate with relevant stakeholders
  ○ SP 2.1 Manage stakeholder involvement
  ○ SP 2.2 Manage dependencies
  ○ SP 2.3 Resolve coordination issues
		• SG 1 Use the defined process for the work
		  ○ SP 1.1 Establish the defined process
		  ○ SP 1.2 Use organizational process assets for planning work activities
		  ○ SP 1.3 Establish the work environment
		  ○ SP 1.4 Integrate plans
		  ○ SP 1.5 Manage the work using integrated plans
		  ○ SP 1.6 Establish Teams
		  ○ SP 1.7 Contribute to Organizational Process Assets
		• SG 2 Coordinate and collaborate with relevant stakeholders
		  ○ SP 2.1 Manage stakeholder involvement
		  ○ SP 2.2 Manage dependencies
		  ○ SP 2.3 Resolve coordination issues	

Table 24 Decision Analysis And Resolution

PA name in MM-TSVC:	Decision analysis and resolution	PA name in CMMI-SVC:	Decision Analysis and Resolution
Purpose in MM-TSVC:	The purpose is to analyze possible decisions using a formal evaluation process that evaluates identified alternatives against established criteria.	Purpose in CMMI-SVC:	The purpose is to analyze possible decisions using a formal evaluation process that evaluates identified alternatives against established criteria.
• SG 1 Evaluate Alternatives ○ SP 1.1 Establish Guidelines for Decision Analysis ○ SP 1.2 Establish Evaluation Criteria ○ SP 1.3 Identify Alternative Solutions ○ SP 1.4 Select Evaluation Methods ○ SP 1.5 Evaluate Alternative Solutions ○ SP 1.6 Select Solutions		• SG 1 Evaluate Alternatives ○ SP 1.1 Establish Guidelines for Decision Analysis ○ SP 1.2 Establish Evaluation Criteria ○ SP 1.3 Identify Alternative Solutions ○ SP 1.4 Select Evaluation Methods ○ SP 1.5 Evaluate Alternative Solutions ○ SP 1.6 Select Solutions	

Table 25 Risk Management

PA name in MM-TSVC:	Risk management	PA name in CMMI-SVC:	Risk Management
Purpose in MM-TSVC:	Same as in CMMI-SVC	Purpose in CMMI-SVC:	Identify potential problems before they occur so that risk handling activities can be planned and invoked

Same as in CMMI-SVC		• SG 1 Prepare for Risk Management
		  ○ SP 1.1 Determine Risk Sources and Categories
		  ○ SP 1.2 Define Risk Parameters
		  ○ SP 1.3 Establish a Risk Management Strategy
		• SG 2 Identify and Analyze Risks
		  ○ SP 2.1 Identify Risks
		  ○ SP 2.2 Evaluate, Categorize, and Prioritize Risks
		• SG 3 Mitigate Risks
		  ○ SP 3.1 Develop Risk Mitigation Plans
		  ○ SP 3.2 Implement Risk Mitigation Plans	

Table 26 Organizational Test Process Performance

PA name in MM-TSVC:	Organizational test process performance	PA name in CMMI-SVC:	Organizational Process Performance
Purpose in MM-TSVC:	Same as in CMMI-SVC	Purpose in CMMI-SVC:	Establish and maintain a quantitative understanding of the performance of selected processes
Same as in CMMI-SVC		• SG 1 Establish Performance Baselines and Models o SP 1.1 Establish Quality and Process Performance Objectives o SP 1.2 Select Processes o SP 1.3 Establish Process Performance Measures o SP 1.4 Analyze Process Performance and Establish Process Performance Baselines o SP 1.5 Establish Process Performance Models	

Table 27 Organizational Test Project Performance (Quantitative Test Project Management)

PA name in MM-TSVC:	Organizational test project (Quantitative test project performance management)	PA name in CMMI-SVC:	Organizational Project Performance (Quantitative Work Management)
Purpose in MM-TSVC:	Same as in CMMI-SVC	Purpose in CMMI-SVC:	Quantitatively manage the work to achieve the established quality
Same as in CMMI-SVC		• SG 1 Prepare for Quantitative Management o SP 1.1 Establish the Work Objectives o SP 1.2 Compose the Defined Process o SP 1.3 Select Sub-processes and Attributes o SP 1.4 Select Measures and Analytic Techniques • SG 2 Quantitatively Manage the Work o SP 2.1 Monitor the Performance of Selected Sub-processes o SP 2.2 Manage Work Performance o SP 2.3 Perform Root Cause Analysis	

Table 28 Organizational Test Process And Performance Improvement

PA name in MM-TSVC:	Organizational test process and performance improvement	PA name in CMMI-SVC:	Organizational Performance Management
Purpose in MM-TSVC:	Same as in CMMI-SVC	Purpose in CMMI-SVC:	The purpose is to proactively manage the organization's performance to meet its business objectives.
Same as in CMMI-SVC		• SG 1 Manage Business Performance o SP 1.1 Maintain Business Objectives o SP 1.2 Analyze Process Performance Data o SP 1.3 Identify Potential Areas for Improvement SG 2 Select Improvements • SG 2 Select Improvements o SP 2.1 Elicit Suggested Improvements o SP 2.2 Analyze Suggested Improvements o SP 2.3 Validate Improvements o SP 2.4 Select and Implement Improvements for Deployment • SG 3 Deploy Improvements o SP 3.1 Plan the Deployment o SP 3.2 Manage the Deployment o SP 3.3 Evaluate Improvement Effects	

Table 29 Causal Analysis And Resolution

PA name in MM-TSVC:	Causal analysis and resolution	PA name in CMMI-SVC:	Causal Analysis and Resolution
Purpose in MM-TSVC:	Same as in CMMI-SVC	Purpose in CMMI-SVC:	The purpose is to identify causes of selected outcomes and take action to improve process performance.
Same as CMMI-SVC		• SG 1 Determine Causes of Selected Outcomes o SP 1.1 Select Outcomes for Analysis o SP 1.2 Analyze Causes • SG 2 Address Causes of Selected Outcomes o SP 2.1 Implement Action Proposals o SP 2.2 Evaluate the Effect of Implemented Actions o SP 2.3 Record Causal Analysis Data	

CHAPTER 3

CASE STUDY: APPLICATION AND EVALUATION OF THE MODEL

To assess the applicability and usefulness of the MM-TSVC model, a case study was designed and conducted using the model in two industrial settings.

3.1 Case-study Design

3.1.1 Goal, research questions and metrics

of stakeholders involved in software testing services (e.g., service providers and customers). 'Completeness' of the model in this context denotes whether it capture all the Stated using the goal template of the Goal/Question/Metric (GQM) approach [30], the goal of case study is to assess the applicability and usefulness of the MM-TSVC model when it is applied in real industrial settings to assess the maturity of software testing services w.r.t. 'completeness and relevance' of the model (defined below), from the point of view important aspects in the scope of maturity of testing services. 'Relevance' in this context denotes whether all the factors and issues included in the model are relevant, i.e., should be assessed.

As the above goal shows, the nature of this case study is 'exploratory' [31] in that work objective was to find out what is happening, to seek new insights, and to generate ideas and hypotheses for follow-up improvement and research.

3.1.2 Case (context): two industrial settings

Using my active industrial connections and partnerships, the case study was conducted in partnership with two industrial companies which have provided software testing services in the last several years. For anonymity purposes, these two companies was referred as C1 and C2. Both C1 and C2 provide software testing services actively in different domains in Turkey, e.g., government and defence. In terms of company sizes, both companies are Small and Medium-sized Enterprises (SMEs). In a given time, each company provides testing services to multiple clients in the scope of several different testing projects. The projects are from different spectrums of software testing, e.g., functional and non-functional testing. The

author's belief that these two companies are very good representative of firms providing software testing services.

Direct connections have been established with several test engineers and managers in both C1 and C2 and have collaborated on other projects in the past. A test manager from C1 (TM1) and a test manager from C2 (TM2) agreed to be actively involved in this joint work for the case study purposes. Both TM1 and TM2 are regularly involved in multiple software testing service projects in the roles of service provider team leads. Thus, they were the best subjects to be involved in the case study. Case-study's execution was discussed next and the results were presented for the four RQs.

3.2 Case-study Execution: Application Of The Model

After case-study design, the case-study was executed. That included application of the MM-TSVC model on each of the C1 and C2 cases, to extract the maturity assessment results, and to answer the four RQs of the study. For this purpose, regular meetings were set upped with TM1 and TM2 for the duration of several weeks. The iterative work started with a thorough introduction of the model by the researchers to TM1 and TM2 and several of their colleagues (test engineers working under their supervision) who were going to be also involved in the study.

All the items (SGs and SPs) were stored in an Excel spreadsheet and were ranked, using the following scheme, and also ensuring that proper justifications/documentations were recorded for each item. A 5-point Likert scale was used for ratings each SP suggested by the Standard CMMI Appraisal Method for Process Improvement (SCAMPI) [32]: (0) not implemented, (1) partially implemented (PI), (2) largely implemented (LI), (4) fully implemented (FI), and (5) not yet (NY) or not applicable (N/A).

3.3 Case-study Results

After careful application of the model and case-study execution, as discussed in Section 4.3, the scores for each SP were recorded along with the corresponding evidence and supporting documentations/ justifications in a spreadsheet (an excerpt of which is shown in Figure 15).

	A	B	C	D	E
1		Process area	Specific goal and practices	NI, PI, LI, FI, N/A	Comments / justifications
2	1	Test service agreement establishment and delivery	· SG 1 Establish Service Agreements		
3			o SP 1.1 Analyze test service and customer needs	LI	1-2 weeks time for analyzing needs but because of security issues we can't analyze all details
4			o SP 1.2 Discus and negotiate elements of the Test Service Agreement (contract), e.g., basic details such as test requirements, duration/cost , and other issues that we have heard from our industry partners such as regression tests and when to stop	FI	Meetings with customers before bidding.
5			o SP 1.3 Establish the test Service Agreement (contract)	FI	We always have contracts.
6			· SG 2 Prepare for Service Delivery		
7			o SP 2.1 Establish the Test Service Delivery Approach	FI	Usually described by the customer in contracts.
8			o SP 2.2 Prepare for Test Service Operations (mostly internal to the test team)	FI	
9			· SG 3 Deliver Services		
10			o SP 3.1 Receive and Process Service Requests	FI	Requests are fixed at the beginning of the
11			o SP 3.2 Operate the Service System (including test staff, test processes and test activities)	FI	
12			o SP 3.3 Maintain the Test Service System (including test staff, test processes and test activities)	NA	We do not have a specific system. We work in project based contracts.

Figure 15 An excerpt from the spreadsheet in which the corresponding evidence and supporting documentations/ justifications for scoring each SP were logged in detail

Figure 16 shows the maturity assessment results using MM-TSVC for each of the two industrial cases.

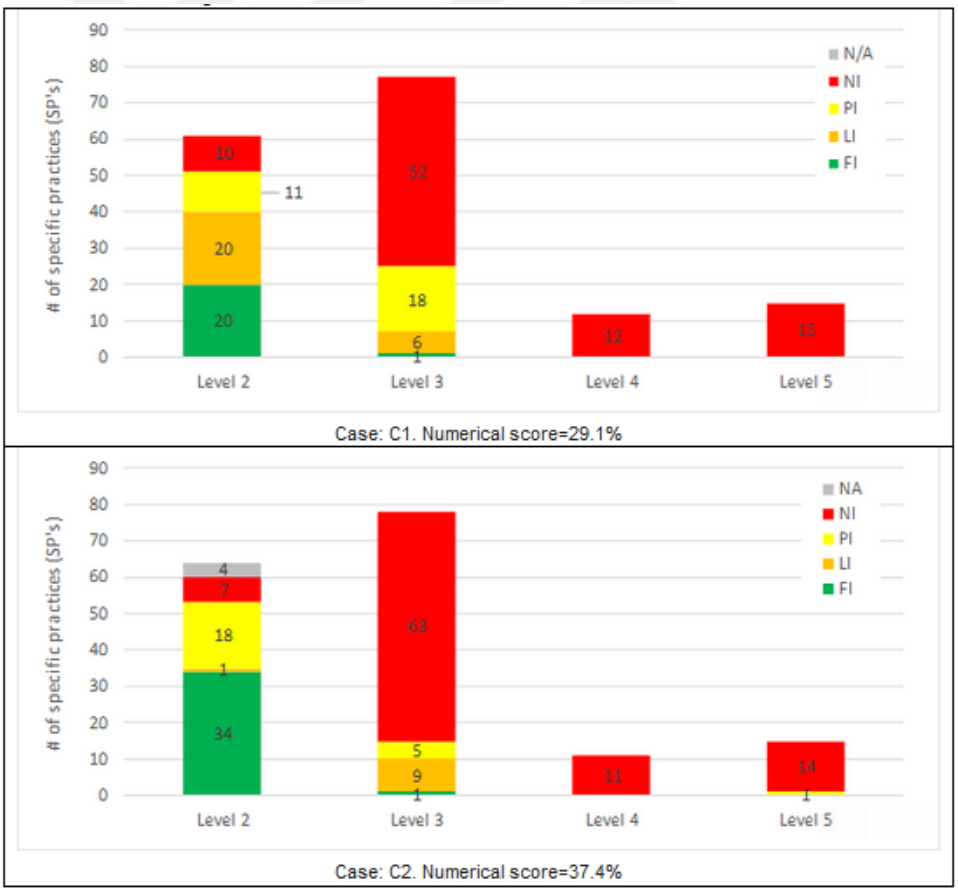

Figure 16 Maturity assessment results using MM-TSVC for each of the two industrial cases.

Since the type of maturity models can be either ‘staged’ or ‘continuous’, and since both MM-TSVC and CMMI-SVC are both ‘staged’ models, it can be seen in Figure 16 that, in none of the two industrial cases, no single level has been ‘fully’ implemented (all green bars denoting ‘FI’). This means that none of the firms were able to get the full maturity assessment for any of the levels (even level 2). I discuss next some concrete examples of the Specific Practices (SPs) which received ratings of Fully Implemented (FI), Largely Implemented (LI), Partially Implemented (PI), or Not Implemented (NI) in each of the industrial cases.

For the case C1, only 20 out of the 61 SPs in levels are FI, e.g., SP 1.1 (Understand test requirements as documented in the test service agreement). 20 SPs are also LI, e.g., SP 1.2 (Manage test requirements changes). Again for the case of C1, 89 out of the total 156 SPs (48.9%) are NI. The situation for C2 is slightly better in terms of having 52 SPs as NI. But in summary, the need for improvements in the case of both test service companies in seen.

The author also wanted to numerically assess and compare the two cases. The author used a weighting scheme to calculate a single percentage score for each of the cases. The author assigned 3, 2, 1, and 0, respectively, to ranks of FI, LI, PI, and NI (and N/A) and summed the values. Such a numerical assessment is also popular in the traditional software process improvement (SPI) literature, e.g., [54]. An assessment of all FI ranks for all the 156 SPs would yield a value of 495. The numerical scores for the two cases were 29.1% and 37.4%, respectively.

The assessment and the ranks of FI, LI, PI, NI and N/A clearly and explicitly showed to the test managers and researchers the areas needing improvement in each case. Improvement activities have started in both the companies and are currently underway.

CHAPTER 4

CONCLUSIONS AND FUTURE WORKS

This work proposed a maturity model (called MM-TSVC) for assessing the maturity of software testing services which was developed based on the principles of the 'CMMI for Services' (CMMI-SVC) model and in close collaboration with several industry partners offering software testing services. To assess the applicability and usefulness of the model, the author evaluated the model in two industrial settings by applying it in two companies who provide software testing services in Turkey. The quantitative and qualitative results of the case study have shown that the proposed model has been indeed useful and helpful for both companies and their test management teams by helping them objectively assess the maturity of their testing services and also to pinpoint potential improvement areas.

In terms of the model's development strategy, the author followed an iterative approach, i.e., the author developed a first version and evolved it multiple times in joint effort among the authors who were a mix of industry practitioners and academic researchers. This was done to ensure that the model would meet the needs of the software testing industry. To further ensure the industrial suitability of the model, the author considered two important criteria while developing the model: completeness and relevance.

My future work directions include the followings: (1) further empirical application of the model by applying it in more industrial settings and to further improve the model; (2) conducting empirical studies on the relationship of the maturity score as assessed by this model and the quality of testing services offered, i.e., does a high maturity score necessarily translate to high-quality testing services?; and (3) studying the correlations among the TMMI, CMMI and MM-TSVC ratings of a given industrial context.

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