

Workflow Models to Establish Software Baselines in SSMEs

Islam Ali¹, Wasif Nisar¹, Waqar Mehmood², Muhammad Qaiser Saleem³, Ali S. Ahmed³, Haysam E. Elamin⁴, Mahmood Niazi⁵ and Muhammad Shafiq^{6,*}

¹Department of Computer Science, COMSATS University Islamabad, Wah, Pakistan

²Department of IT and Computer Science, PAF-Institute of Applied Sciences and Technology, Haripur, Pakistan

³College of Computer Science and Information Technology, Al Baha University, Al Baha, Saudi Arabia

⁴Department of Information Technology, Faculty of Computer Science and Information Technology, University of Jeddah, Jeddah, Saudi Arabia

⁵Department of Information and Computer Science, King Fahd University of Petroleum and Minerals, Dhahran, 31261, Saudi Arabia

⁶Department of Information and Communication Engineering, Yeungnam University, Gyeongsan, 38541, Korea

*Correspondence: Muhammad Shafiq. Email: shafiq@ynu.ac.kr

Received: 31 December 2020; Accepted: 21 February 2021

Abstract: Capability Maturity Model Integration (CMMI) is used for Software Process Improvement (SPI) worldwide. Research reveals that CMMI adoption needs a lot of resources in terms of training, funds, and professional workers. Software Small & Medium Enterprises (SSMEs) cannot, however, reserve resources for the purpose. One of the challenges of CMMI adoption is that CMMI identifies “What-to-Do” as a requirement to fulfill and leaves “How-To-Do” to implementers. Implementation of Configuration Management Process Area (CM-PA), being one of the umbrella activities, presents more obstacles generally to the software industry and particularly to SSMEs as compared to other PAs. *Establish software baselines* is the first Specific Goal (SG-1) needed by CMMI for the effective implementation of CM-PA. Workflow Models (WFMs), an identified set of activities performed in a logical sequence to accomplish a specific practice with probable actors and potential work products, were designed for implementation of its three contributing Specific Practices (SPs). The proposed WFMs were evaluated through the Expert Panel Review (EPR) process. Additionally, a case study was conducted to validate the proposed models. The results of the EPR/Case Study showed that the proposed WFMs are useful, easy to use, supportive in the achievement of SG-1, and applicable to SSMEs. It is important to mention that this research work adds to the empirical software engineering body of knowledge as well as contribute to the implementation of CM-PA.

Keywords: SPI; CMMI; CM-PA; SSMEs

1 Introduction

There is no global definition of SSMEs. However, the software enterprises having employees from 6 ~ 250 are considered as SSMEs. The success or failure of SSMEs depends upon the quality of their products or services. Clients expect high-quality software that runs flawlessly and never crashes. One way



This work is licensed under a Creative Commons Attribution 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

to improve quality is to improve software development processes. Continual software process improvement and periodic appraisal for effectiveness are bound to pave the way towards high-quality software. It cannot be denied that the CMMI model helps the software industry to take the quality of its software development process to higher levels. However, no significant number of SSMEs decide to adopt it. Xu et al. [1] believe that CMMI offers software enterprises only guidelines and does not provide clear workflow models.

CMMI Level-II [2] comprises seven PAs, including CM-PA. A wide range of research has been carried out for the implementation of PAs at Level-II. However, no workflow model was found for establishing a baseline to help SSME, as shown in Tab. 1. Consequently, there is an urgent need to develop configurable workflow models for this purpose.

Table 1: Summary of workflow models devised earlier for various SPs of PAs at CMMI Level-II

| No | PAs at CMMI Level-II | Work | Ref. |
|----|---------------------------------------|--|-------|
| 1 | Project Planning | WFM for SP-1.3 | [3] |
| 2 | Process and Product Quality Assurance | WFM for PPQA | [4] |
| 3 | Requirements Management | WFMs for SPs (1.1, 1.2) & SPs (1.3, 1.4) of REQM, WFM for CR, Remap: of KPAs of L-2 for SAS, RCM | [5–9] |
| 4 | Supplier Agreement Management | WFM for SAM | [10] |
| 5 | Configuration Management | X | X |
| 6 | Measurement & Analysis | X | X |
| 7 | Project Monitoring & Control | X | X |

This study aims to achieve SG-1 of CM-PA by designing WFMs for the implementation of its three SPs. Research questions, as shown in Tab. 2, have been formulated to achieve the specified research objectives.

Table 2: Questions with research rationale

| No | Questions | Rationale |
|-----|--|---|
| R-A | How to achieve SG-1 of CM-PA i.e. how to establish baselines? | To devise WFMs for implementation of SPs of CM-PA |
| R-B | What is the expert’s perception of the “Coverage” of WFMs proposed for SG-1 of CM-PA from the perspective of software SMEs? | To assess its coverage, |
| R-C | What is the expert’s perception of the “Usefulness” of proposed WFMs for establishing baselines w.r.t software SMEs? | ease of use and ease of learning, |
| R-D | What is the expert’s perception of the “Ease of Learning & Usage” of proposed WFMs for SG-1 taking Software SMEs into account? | Usability and |
| R-E | What is the expert’s perception of the “Applicability” of the proposed WFMs to Software SMEs? | Implement-ability in Software SMEs. |

2 Research Methodology

Research methodology has always been considered to have a profound impact on the study, so it was very meticulously designed. The phases involved in the designing of the WFMs are illustrated in Fig. 1.

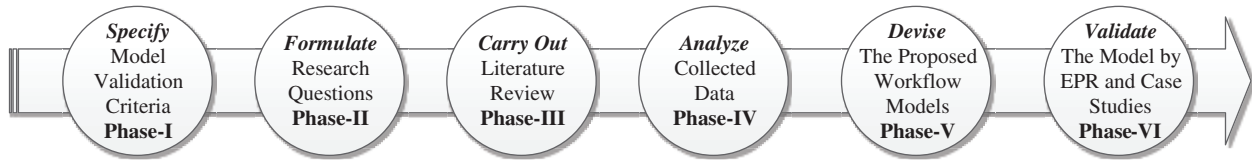


Figure 1: Research methodology

Identification of the criterion is the first phase of this research methodology. The criterion, because of its similar nature, was derived from the work of Keshta [3–6], and Niazi et al. [9] respectively, as briefed in Tab. 3. The rest of the phases, being self-explanatory, need not be further elaborated.

Table 3: Validation criteria

| Criteria | Validation |
|--|---|
| <i>Satisfaction of SPs</i> | The proposed WFMs must address the practices to achieve goals set by CMMI v1.3. |
| <i>Satisfaction of Users</i> | The model should satisfy users and help them achieve their needs and goals. |
| <i>Ease of Learning & Use</i> | The model should be simple, easy to understand, and easy to adopt. |
| <i>Applicability of models to SSMEs.</i> | WFMs should be implementable in SSMEs, that is, they should enable them to establish baselines. |

3 Related Work

A variety of related research was explored. However, for brevity, only very close research, i.e., WFMs designed for implementation of PAs at CMMI Level-II is presented. Keshta [3] devised a WFM for implementation of SPs 1.3 of PP-PA and defined phases for a project life cycle keeping in view the SSMEs. The model comprises four stages: “Plan”, “Design”, “Review”, and “Update / Rework”. Keshta et al. [4] further developed WFMs for all SPs of PPQA-PA from the perspective of SSMEs. Two of the SPs, (SP - 1.1 and SP - 1.2) of PPQA comprise four stages i.e., “Plan”, “Prepare”, “Audit” & “Report”. The models were validated using EPR. Besides, Keshta et al. [5] designed WFMs for four SPs of REQM-PA to support SSMEs to implement the best practices. The five phases of the WFM for SP 1.1 are: “Request”, “Understand”, “Evaluate”, “Accept” and “Finalize”. SP 1.2 also include five stages: “Assess”, “Report”, “Negotiate”, “Record”, and “Commit”. The WFMs [6] for SP 1.3 has six stages: “Initiate”, “Validate”, “Implement”, “Verify”, “Update” and “Release” whereas WFM for SP 1.4 also constitutes six stages: “Request”, “Maintain”, “Validate”, “Allocate”, “Verify” and “Release”. The EPR process was used to validate the WFMs using the specified criteria. The applicability of models to SSMEs was evaluated in Saudi Arabian software industry.

Other researchers have also done similar work. Tariq et al. [7] proposed that an additional SP be included in REQM-PA for Software as a Services (SAAS) and carried out validation through a case study “Allwebid”. Similarly, Batti et al. [8] proposed a six-phase methodology to deal with changing requirements i.e., “Initiate”, “Receipt”, “Approve/Disapprove”, “Evaluate”, “Implement” and “Configure” with CCB to act as a central player and process owner. In the same manner, Niazi et al. [9] developed the

CMMI-compliant Requirements Change Management (RCM) Model with five stages: “Request”, “Validate”, “Implement”, “Verify” & “Update” which was evaluated through the EPR process. Consequently, Vivatanavorasin et al. [10] proposed a three-layer WFM for SAM-PA containing “Contextual layer,” “Elaboration layer”, and “Description layer”. A tool was also developed for Supplier Agreement Management as a proof-of-concept prototype.

After a thorough literature review, it was found that no WFM is available. However, there is an acute need to design WFMs to support the implementation of SG-1 in SSMEs.

4 Proposed Workflow Models

The first SG of CM-PA “Establish Baselines” is achieved through three SPs.

4.1 Identify Configuration Items

WFM for the first SP has five stages namely: “Planning”, “Identification”, “Assignment”, “Documentation” and “Sharing” as illustrated in Fig. 2. Supportive pieces of evidence are shown in Tab. 4 and a pertinent process guide is given in Tab. 5.

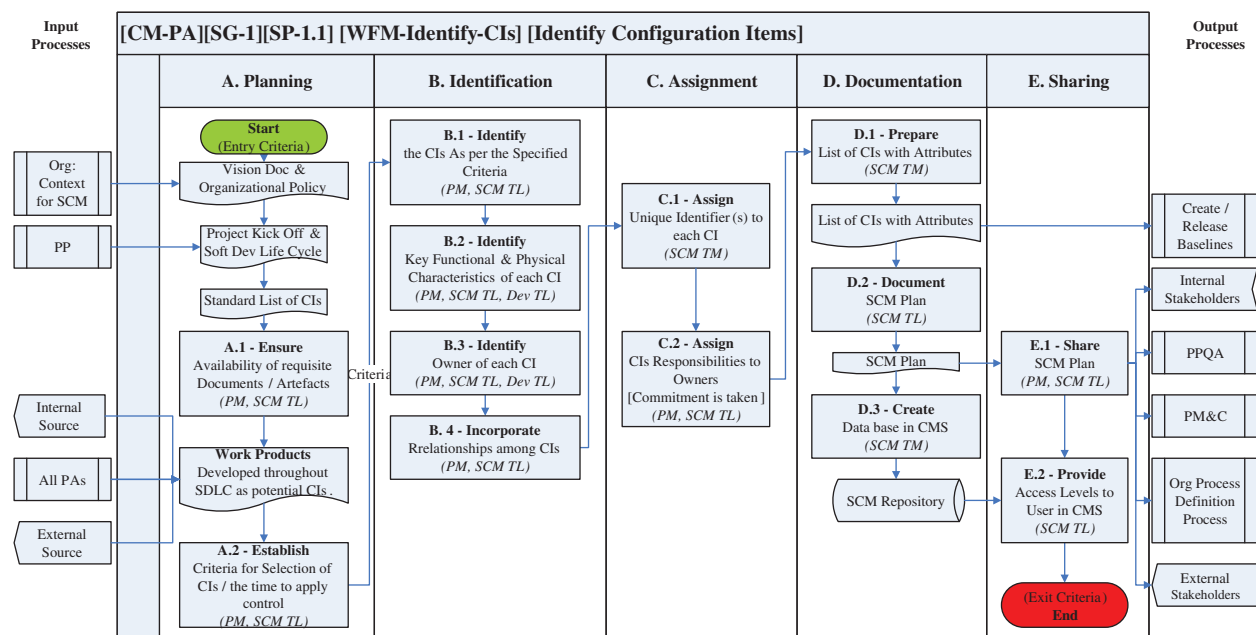


Figure 2: Proposed workflow model to identify configuration items (SP - 1.1)

4.2 Establish Configuration Management System

Few among the findings supportive of the proposed WFM are given in table Tab. 6. The proposed WFM is divided into five stages i.e., “Planning”, “Establishment”, “Maintenance”, “Preservation” and “Improvement” and is illustrated in Fig. 3 followed by the pertinent process guide in Tab. 7.

4.3 Create or Release Baselines

Proposed WFM for creating/releasing baselines is divided into four stages i.e., “Initiation”, “Authorization”, “Creation” and “Release” and is illustrated in Fig. 4. Only two of the supportive findings from literature are given in Tab. 8 and the pertinent process guide in Tab. 9.

Table 4: Evidences from the literature supporting the proposed WFM for identification of CIs

| No. | Evidences | Author's point of view | Reference |
|--------------------------------|---|--|--------------------------|
| A – Planning Stage | | | |
| 1 | Software Engineering Body of Knowledge. | The SCM planning, for a project, shall be aligned to the organ: context, vision, policies, and constraints, and nature of the project. Selection of Software Development Life Cycle (SDLC) also affects the identification of software configuration items (SCIs). | SWEBOK [11] |
| 2 | CMMI for Development | According to the author, key artifacts should be flagged for control during project planning. Criteria for consistent identification of CI should be established. You can also select configuration items based on business/ technical requirements. | Chrissis et al. [12] |
| B – Identification | | | |
| 1 | Software Engineering Body of Knowledge | Regarding the choice of the number of SCIs, a balance should be struck between manageability and visibility of project control. As structural relationships between SCIs or their components impact other SCIs / activities, it is necessary to track these relationships for traceability and keeping in view while devising a scheme for the identification of SCIs. | SWEBOK [11] |
| 2 | CMMI for Development Ver. 1.3 | Identification of SCIs is basically to select/specify deliverables, WPs for internal use, and tools acquired. The selection of WPs shall be based on criteria usually set out in the planning phase. | CMMI Product Team [2] |
| C - Assignment Stage | | | |
| 1 | CMMI for Development – Implementation Guide | A scheme shall be devised to compose/assign a unique identification mark to each CI and identify a point when / where to control each CI e.g. based on readiness for the test, milestones, degree of control, ownership, etc. | M. Chaudhary et al. [13] |
| 2 | CMMI for Development | Usually, product life exceeds the project life. Responsibility for CIs changes as the project move on. CM tool usually assign unique identifiers to CIs automatically | Chrissis et al. [12] |
| D - Documentation Stage | | | |
| 1 | Software Engineering Body of Knowledge | SCM planning activities for a project shall result in a living document referred to as SCM Plan serving as a reference. It shall be approved and maintained throughout the SDLC. | SWEBOK [11] |

(Continued)

| Table 4 (continued). | | | |
|-----------------------------|--|--|--------------------------|
| No. | Evidences | Author's point of view | Reference |
| 2 | Introduction to Software Quality Assurance | An SCM Plan shall be devised in initial stages whether included in the project plan or is a separate artifact, it shall specify the CM activities including identification of CIs and itself placed under control. | O'Regan [14] |
| E - Sharing Stage | | | |
| 1 | CMMI for Development | Ensure that relevant stakeholders are aware of the status of CIs including the SCM Plan (i.e. share the status and inform about the CM activities.) | M. Chaudhary et al. [13] |
| 2 | CMMI for Development | You must strike a balance between that all who need access to CIs, must have it and the need for access is genuinely assessed. | Chrisis et al. [12] |

Table 5: A process guide for WFM to identify CIs

| | | | |
|--|---|---|------------------------------------|
| Purpose | The purpose of this process is to initiate the identification of CIs activities to be performed throughout the life cycle of a project in a pre-defined manner i.e. based on established criteria. The configuration of these items is maintained throughout the SDLC. | | |
| Scope | The scope of the SCM planning process lies within the Project Planning process. The SCM Team Lead (TL) may lead all the activities of this process in coordination with the PM. An SCM plan document is developed by the SCM team and is reviewed and approved by the PM. | | |
| Abbreviations | <ul style="list-style-type: none"> • CIs • CMS • SRS | <ul style="list-style-type: none"> Configuration Item Configuration Management System Software Requirements Specifications | |
| Entry criteria | <ul style="list-style-type: none"> • A vision document has been shared to initiate the process. • The project has been kicked off and a kick-off email sent to all to start the SCM planning activities. | | |
| Inputs to the workflow and associated PAs/SPs | Input Work-Products | Associated PAs / SPs | |
| | <ul style="list-style-type: none"> • Vision Document, Organizational Policy • Requirements Specifications | <ul style="list-style-type: none"> • Organizational Process Definition • Requirements Management | |
| Stage | Process Activities | Roles | WPs/Records |
| A. Planning | A.1 As a first stage, the availability of all relevant artifacts required for the identification of CIs is ensured e.g. A standard list of CIs or a list of CIs of a similar project. | PM, SCM TL | – |
| | A.2 To maintain consistency in the selection of CIs and specify when to apply control on each CIs throughout the project, criteria shall be established. | PM, SCM TL | Criteria for Identification of CIs |

| Table 5 (continued). | | | | |
|---|-----|---|--|--|
| B. Identification | B.1 | The CIs shall be identified as per the specified criteria. | PM, SCM TL | Identified CIs with characteristics, owners, and relationships |
| | B.2 | Key functional & physical characteristics shall be identified of each CI. | PM, SCM TL, Dev TL | |
| | B.3 | The owner of each CI shall be identified. | SCM/Dev TL | |
| | B.4 | The relationship between CIs shall be identified. | PM, SCM TL | |
| C. Assignment | C.1 | A unique identifier is assigned to each CI. | SCM TM | - |
| | C.2 | Responsibilities for each CI is assigned to owners. | PM, SCM TL | |
| D. Documentation | D.1 | A list of CIs shall be documented. | SCM TM | List of CIs |
| | D.2 | SCM Plan shall also be documented. | SCM TL | SCM Plan |
| | D.3 | Data for CIs shall be created in CMS. | SCM TM | - |
| E. Sharing | E.1 | SCM Plan / List of CIs shall be shared among stakeholders | PM, SCM TL | Sharing Logs |
| | E.2 | Access level shall be provided to all authorized users. | SCM TL/TMs | Access Levels |
| Interfaces | | <ul style="list-style-type: none"> • Project Plans – Project Planning Process, Project Monitoring and Control Process • SRS- Requirements Management | | |
| The output of the workflow with associated PAs/SPs | | Output Work-Products <ul style="list-style-type: none"> • A list of CIs • SCM Plan | Associated PA / SP <ul style="list-style-type: none"> • Create or Release Baselines • PP-PA | |
| Exit criteria | | <ul style="list-style-type: none"> • An approved list of CIs is prepared. • User access is defined. • SCM Plan reviewed and approved by the relevant stakeholders | | |
| Verification points | | <ul style="list-style-type: none"> • PM in coordination with Dev TL and SCM TL shall review the SCM planning process and work products i.e., the list of CIs, SCM Plan, etc. • QA shall evaluate the CI identification process and CIs. • Higher-level management periodically shall review the SCM planning activities. | | |
| Training | | <ul style="list-style-type: none"> • Training on configuration identification process guide • Templates usage training | | |
| Tools | | <ul style="list-style-type: none"> • MS Word / MS Excel | | |
| Resources | | <ul style="list-style-type: none"> • Process descriptions and tailoring guidelines | | |
| Assumptions | | <ul style="list-style-type: none"> • The project has been kicked off and the planning process is started • A standard list of CIs are available and updated / CMS is in place / operational | | |
| Exemptions | | <ul style="list-style-type: none"> • Tailoring Guidelines | | |
| Applicable standards/docs | | <ul style="list-style-type: none"> • Documentation Standards Manual, Tailoring Guidelines • Project Monitoring and Control Process Guide, Requirements Management Process Guide | | |

Table 6: Evidences from the literature supporting proposed WFM to establish CMS

| No. | Evidences | Author's point of view | References |
|--------------------------------|---|--|--------------------------|
| A – Planning Stage | | | |
| 1 | CMMI for Development | Plan to establish a system for change request includes the formation of CCB aimed to review/evaluate baselines for approval, rejection, or batch for future. | Chrisis et al. [12] |
| 2 | Software Engineering Body of Knowledge | As per SWEBOK, criteria for tool selection includes an organizational perspective on tool acquisition, buy or develop a decision, technical context, financial position, tool usage for legacy/present/future projects, ownership, adaptability, integration, migration, size/type of the project to be maintained, etc. | SWEBOK [11] |
| B – Establishment Stage | | | |
| 1 | CMMI for Development | Many turnkey systems are available to help you with CM. Before you purchase one, identify your needs and compare them to the system's features. | Chrisis et al. [12] |
| 2 | Introduction to Software Quality Assurance. | As per the author, CMS shall have a Unified Directory Structure for handling project files and shall be able to provide records of all CM activities & status of Cis. Revision history of Cis shall be maintained | O'Regan [14] |
| C – Maintenance Stage | | | |
| 1 | CMMI for Development | In CMS, provision of access to every stakeholder shall be maintained as per their roles i.e. authorized stakeholders have privileges to relevant Cis only. | M. Chaudhary et al. [13] |
| 2 | CMMI for Development | The majority of SSMEs opt for an automated SCM tool as it's nearly impossible to maintain a CM process manually. | Chrisis et al. [12] |
| D – Preservation Stage | | | |
| 1 | CMMI for Development | Every Check-in / Check-out shall be carried out in a manner that no previous version is lost i.e. each CI is recoverable and its status is known. | M. Chaudhary et al. [13] |
| 2 | Software Engineering Body of Knowledge. | Surveillance of SCM is necessary to have a focus on SCM insights, to ensure the smooth operation of SCM. Security and backup facilities shall be key elements of the SCM tool and shall be capable to reproduce previous releases for additional release, testing, maintenance, recovery, etc. | SWEBOK [11] |
| D – Improvement Stage | | | |
| 1 | CMMI for Development | SCM shall be very easy to use to ensure that no one tries to avoid/bypass it and be reviewed periodically for fulfilling the project needs. | Chrisis et al. [12] |
| 2 | Software Engineering Body of Knowledge. | SCM measurement program may be used to make SCM effective. It provides valuable info about evolving products & insight into the SCM functioning and may be used to bring improvements in SCM. | SWEBOK [11] |

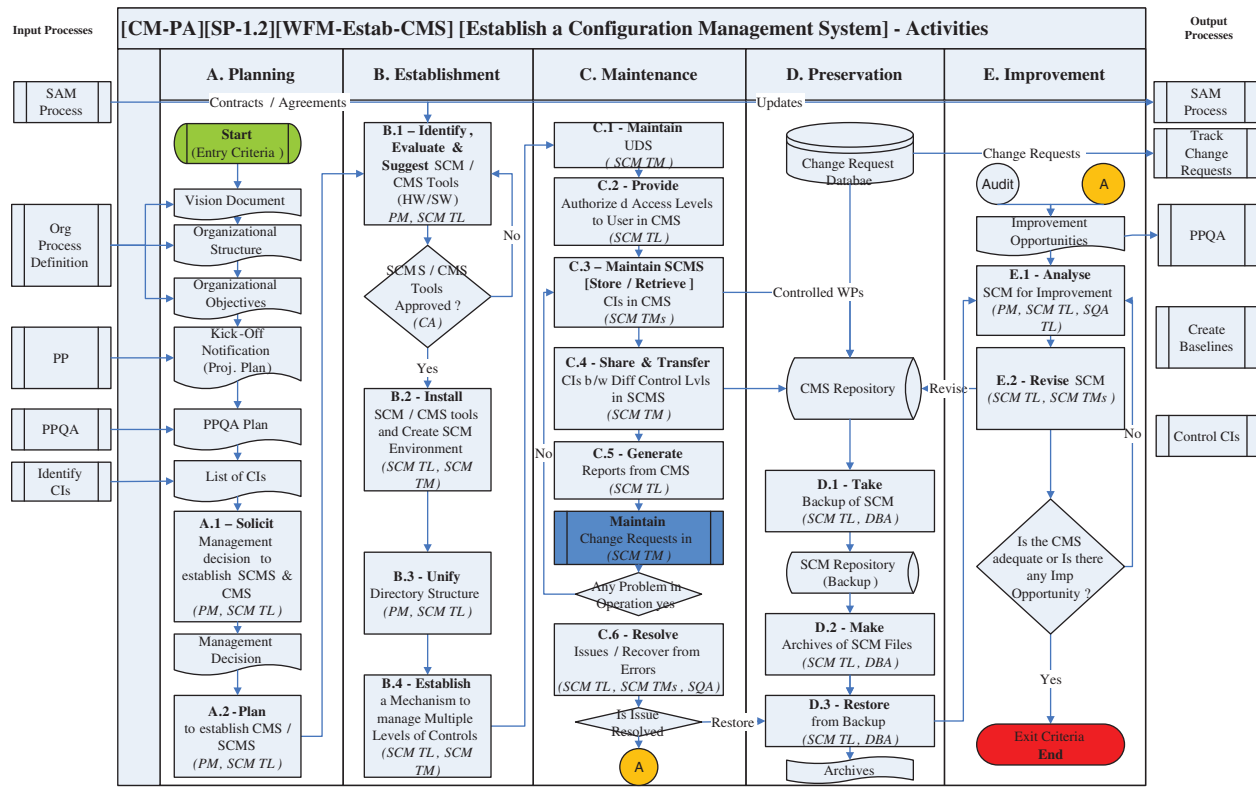


Figure 3: Workflow model for SP - 1.2

Table 7: A process guide for establishing a configuration management system

| | | | |
|--|---|---|---|
| Purpose | The purpose of SP 1.2 is to establish & maintain a CMS for the project’s artifacts and management of multiple levels of control over the repository. CMS is the central repository of the project data, where a Unified Directory Structure (UDS) for each project is created and is maintained throughout the life of the project. | | |
| Scope | The SCM activities may include creation and maintenance of the UDS, Control of CIs by making use of various techniques e.g. creation of access rights for different users as per their roles. | | |
| Abbreviations | <ul style="list-style-type: none"> UDS Unified Directory System SCMS/CSM Software Configuration Management System/Configuration Management System | | |
| Entry criteria | <ul style="list-style-type: none"> SCM plan has been approved. Principal approval by management to establish SCMS has been taken | | |
| Inputs to the workflow & associated PAs/SPs | Input Work-Products <ul style="list-style-type: none"> Approved SCM Plan. List of identified Configuration Items. | Associated PA / SP <ul style="list-style-type: none"> PP-PA Identify CIs | |
| Stage | Process activities | Activity roles | WPs / Records |
| A. Planning | <p>A.1 Management’s decision shall be solicited for establishing Software Configuration Management System (SCMS).</p> <p>A.2 A plan shall be prepared for establishing the said systems.</p> | <p>PM, SCM TL</p> <p>PM, SCM TL</p> | <p>Principle Approval</p> <p>PC-1/ Plan</p> |

(Continued)

Table 7 (continued).

| | | | | |
|-------------------------|-----|---|-------------------------------|--------------------------------------|
| B. Establishment | B.1 | First of all, SCMS / CMS shall be identified, evaluated, and suggesting the candidate CMS meeting the requirements of the software SME. Approval for the purchase of the systems shall be solicited from the competent authority. | PM, SCM TL | Evaluation of proposed CMS |
| | B.2 | Once principal approval is taken, the tools shall be purchased making use of the SAM process. The tools shall be installed and SCMS environments shall be created. | PM, SCM TL, Purchase Manager. | Purchase Records |
| | B.3 | A unified directory structure (UDS) shall be created. This may be used/copied for other projects with or without modifications. | SCM TL, Dev TL PM | UDS in CMS |
| | B.4 | Criteria shall be developed to determine the level of control for CIs and a mechanism shall be established to maintain multiple levels of controls. | SCM TM, SCM TL | Criteria to determine control level. |
| C. Maintenance | C.1 | Unified directory structure shall be maintained | SCM TM | – |
| | C.2 | The provision of access to users shall be decided. | PM, Dev TL | Privileges |
| | C.3 | CMS shall be maintained i.e. storing/retrieving (Checked-In and Checked-Out). | SCM Team | Check-In/Out Logs |
| | C.4 | CIs shall be sharable/transferrable between different control levels. | SCM TMs | – |
| | C.5 | Reports of various kinds may be generated from SCMS | SCM TL/TMs | Reports |
| | C.6 | The CIs shall be restorable from backup /archived files when there are issues/problems in SCMS. | SCM TMs | Backups/ Archives |
| D. Preservation | D.1 | A backup of the entire SCMS database shall be taken. | SCM TMs | – |
| | D.2 | SCMS Files shall also be archived. | SCM TMs | – |
| | D.3 | In case of any issue, backup shall be restored or archived files retrieved to recover the system's state before the problem. | DBA/SCM TMs | Recovery Record |

| Table 7 (continued). | | | | |
|--|--|---|--------------------|---------------------------|
| E. Improvement | E.1 | SCMS shall be analyzed for improvement based on the feedback received from the issues encountered during operation/CM Audits. | PM, SCM TL, SQA TL | Improvement opportunities |
| | E.2 | SCMS shall be revised based on the improvement opportunities. | SCM TL/ TMs | Improvements |
| Interfaces | SCM Plan – Project Planning Process Guide | | | |
| Outputs WPs and associated PAs/ SPs | Output Work-Products (WPs) | Associated PA / SP | | |
| | <ul style="list-style-type: none"> ● UDS ● CMS ● Improvement Opportunities | <ul style="list-style-type: none"> ● Create or Release Baselines, Perform Configuration Audits ● SAM – PA, Create or Release Baselines ● PPQA - PA | | |
| Exit criteria | <ul style="list-style-type: none"> ● Creation of Configuration Management System (Version Control System) ● Creation of UDS in CMS. ● User Access Levels definition | | | |
| Measures | Number of CIs / Size of the Project | | | |
| Verification points | <ul style="list-style-type: none"> ● PM in coordination with Dev TL and SCM TL shall review the <i>Establish / Maintain CMS process</i> and work products based on milestones of the project plan or shall be event-based. ● QA shall evaluate the <i>Maintain CMS</i> process and relevant work products as per the project schedule. ● QC performs testing to ensure the fulfillment of specified requirements as per SRS. ● Top Management shall randomly check the activities, status, and results of the aforesaid process. | | | |
| Training | <ul style="list-style-type: none"> ● Training on VSS, TFS, Clearcase, or any SCM Tool | | | |
| Tools | <ul style="list-style-type: none"> ● MS Word / MS Excel / Any tool on SCM (VSS, TFS, Tortoise, etc.) | | | |
| Resources | <ul style="list-style-type: none"> ● Process descriptions and tailoring guidelines, trained HR having expertise in CM-PA. ● Infrastructure needs (Hardware, Software, Facilities) and adequate/reasonable budget. | | | |
| Assumptions | <ul style="list-style-type: none"> ● PM may direct the creation of CMS/UDS and can assign users before the creation of the SCM Plan. | | | |
| Exemptions | <ul style="list-style-type: none"> ● Tailoring Guidelines | | | |
| Applicable Standards/Docs | <ul style="list-style-type: none"> ● Documentation Standards Manual / Tailoring Guidelines ● Project Planning Process Guide / Project Monitoring and Control Process Guide | | | |

Table 8: Pieces of evidence from the literature supporting WFM for creating or releasing baselines

| No. | Evidence from literature | Author’s point of view | Reference |
|-----------------------------|-------------------------------|--|--|
| A - Initiation Stage | | | |
| 1 | Change Management Strategies. | WFMs devised by Keshta, Bhatti starts with the initiation stage where a request is initiated by the initiator. Because of similar nature, this WFM starts with initiation. | Keshta et al. [6] Bhatti et al. [8] Niazi et al. [9] |

(Continued)

| Table 8 (continued). | | | |
|--------------------------------|---|---|--------------------------|
| No. | Evidence from literature | Author's point of view | Reference |
| 2 | Software Engineering Body of Knowledge. | The competent authority and channels for SCM reporting shall be formally defined. This may be done at the project planning/SQA stage. | SWEBOK [11] |
| B – Authorization Stage | | | |
| 1 | CMMI for Development – Implementation Guide | Chaudhary has the opinion that approval for the creation/release of baselines shall necessarily be taken from CCB. | M. Chaudhary et al. [13] |
| 2 | Interpreting the CMMI | The author has pointed out that CMMI generally refers to none of the specific groups, however, in this practice CCB has been categorically mentioned for approval of baselines. | M. K. Kulpa et al. [15] |
| C – Creation Stage | | | |
| 1 | Introduction to Software Quality | A baseline is a set of WPs reviewed/agreed upon and provides a base for on-going development. CMS shall have a baseline creation facility and a well-defined change/release procedure. | O'Regan [14] |
| 2 | Software Engineering Body of Knowledge | SCM Reports generated e.g. baseline difference reports are used by stakeholders and become records e.g. QA records. | SWEBOK [11] |
| D – Release Stage | | | |
| 1 | Software Engineering Body of Knowledge | Software release entails packaging & delivery of the product. The packaging is the identification of CIs and the selection of correct variants. It also contains installation/upgrading instructions. | SWEBOK [11] |
| 2 | CMMI for Development | Baseline integrity is at high risk if a baseline released is not coming through SCM. | Chrisis et al. [12] |

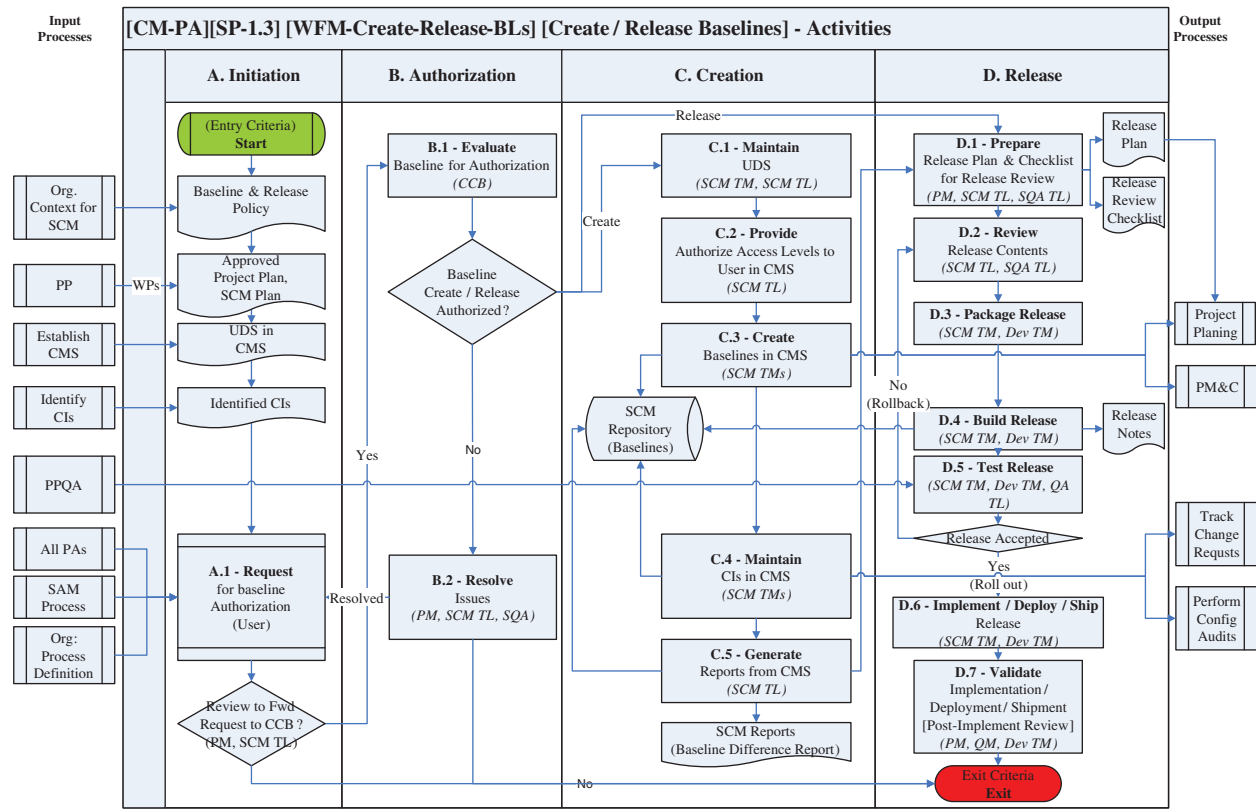


Figure 4: Workflow model for SP - 1.3

Table 9: A process guide for creating/releasing baselines

| | | |
|--|---|---|
| Purpose | This process ensures that once a project work product has been baselined, no changes to it can be made except following the formal <i>Track Change Request</i> procedure. | |
| Scope | This process initiates when respective functionality has been developed, a milestone has been achieved or some issues in the functionality have been resolved. In this process, baselines are created/ released. | |
| Abbreviations | <ul style="list-style-type: none"> ● CCB ● QC | <ul style="list-style-type: none"> Configuration Control Board Quality Control |
| Entry criteria | <ul style="list-style-type: none"> ● Baseline criteria for the Configuration Item(s) have been met. ● After successful completion of bug fixing or completion of a phase, the release label is applied by SCM. ● These labels are identified as a baseline unique identifier in the CMS by SCM. | |
| Inputs to the workflow and associated PAs / SPs | Input Work-Products <ul style="list-style-type: none"> ● In case of artifacts other than code, an email from the respective owner for the base-lining of the artifact shall be issued. ● Confirmation from QC about the resolution of all bugs in a build. ● Labels/tags applied by Dev TL on Dev workspace in the CMS. ● Authorization of baseline from CCB. ● Unique identifier/Label applied by SCM for release. | Associated PA / SP <ul style="list-style-type: none"> ● All process areas ● PPQA-PA ● Technical Solution ● Track Change Requests ● Identify CIs |

(Continued)

| Table 9 (continued). | | | | |
|--|--|---|--------------------|---------------------------------|
| Stage | Activities | Roles | WPs/Records | |
| A. Initiation | A.1 | A request may be initiated by any stakeholder for approval. | User | Requests |
| | A.2 | The request shall be analyzed for sending to CCB for authorization? | PM, SCM TL | – |
| B. Authorization | B.1 | The request shall be evaluated and the decision is given for the creation of baselines or release baseline. | CCB | Authorization Decision |
| | B.2 | The issues identified shall be resolved and put up again for authorization approval. | PM, SCM TL | Issues & their Correct: Actions |
| C. Creation | C.1 | Unified Directory Structure (UDS) shall be maintained by SCM TMs and overseen by SCM TL. | SCM TL, TMs | Maintained UDS |
| | C.2 | All users are provided access as per the requirements of the projects. | SCM TL, TMs, PM | User Access Records |
| | C.3 | Baselines shall be created in SCMS. Baseline labels shall be applied and placed in the release workplace. | SCM TMs | Baselines (Repository) |
| | C.4 | CI shall also be maintained in SCMS. | SCM TMs | Maintained CIs |
| | C.5 | Reports shall be generated as and when needed. | SCM TMs | Baselines Diff: Reports |
| D. Release | D.1 | The release plan shall be prepared along with the checklist for review of baselines to be released. | SCM/SQA /PM | Release Plan |
| | D.2 | Contents shall be reviewed for release. | SCM/SQA TL | Filled Checklists |
| | D.3 | The items/contents to be released shall be packaged. | SCM/Dev TM | Packages |
| | D.4 | The release shall be built. | SCM/Dev TM | Builds |
| | D.5 | The build shall be tested before the actual release. | SCM, QA TL | Test Results |
| | D.6 | The release shall be implemented or deployed or shipped whichever the case may be. | SCM/Dev TMs | Shipment records |
| | D.7 | The release shall be validated i.e., post-implementation review shall be carried out. | PM, QA, Dev TMs | Validation records |
| Interfaces | Updated Project Plans – Project Monitoring & Control Process Area Measures – Measurement & Analysis. | | | |
| The output of the workflow and associated PAs / SPs | Output Work-Products | Associated PA / SP | | |
| | <ul style="list-style-type: none"> ● Request for Authorization of baselines. ● Baselines ● Baseline Difference Reports ● Release(s) | <ul style="list-style-type: none"> ● PMC-PA ● Track Change Requests, Perform Configuration Audits-SPs ● Perform Configuration Audits-SP ● SAM-PA, Organizational Performance Management (OPM) | | |
| Exit criteria | <ul style="list-style-type: none"> ● The baseline review has been performed and the review checklist has been filled accordingly. ● The baselines have been released to clients. | | | |

| Table 9 (continued). | |
|--|---|
| Measures | <ul style="list-style-type: none"> • Number of Baselines, Number of Releases |
| Verification points | <ul style="list-style-type: none"> • PM in coordination with Dev TL and SCM TL shall review the <i>Create or Release Baselines</i> process and work products based on milestones of the project plan or shall be event-based. • QA shall evaluate the <i>Create/Release Baselines</i> process and relevant WPs as per the project schedule. • QC performs testing to ensure the fulfillment of specified requirements as per SRS. • Top Management shall randomly check the progress and effectiveness of creating or releasing practice. |
| Training | <ul style="list-style-type: none"> • Training on Create or Release Baselines and usage of its templates |
| Tools / | <ul style="list-style-type: none"> • MS Word / MS Visio / MS Excel /Any SCMS tool i.e. MS VSS/CVS/ TFS, Clear-Case etc. |
| Resources (HR, Finance) | <ul style="list-style-type: none"> • Process descriptions and tailoring guidelines • Human resources/ Infrastructure needs (Hardware, Software, Facilities) /Appropriate budget |
| Assumptions | <ul style="list-style-type: none"> • Baselining criteria can be defined by the client, however, baseline authorization authority shall be CCB. • Baselines are marked by applying a label/tag in CMS. Baseline identifiers are required for every release. • The project PM, QA TL, and SCM TL are members of the CCB for a project. • A label may be applied to the build in CMS internally by the Dev team for internal testing. |
| Exemptions | <ul style="list-style-type: none"> • Tailoring Guidelines |
| Applicable standard/related documents | <ul style="list-style-type: none"> • Documentation Standards Manual • Process Guides on PM&C, M&A PAs • Tailoring Guidelines |

5 Proposed WFMs Validation

5.1 EPR Process Validation.

An EPR process was carried out to validate the proposed WFMs, where opinions on the models based on the specified criteria were collected from 10 experts with experience in the fields of SPI, Project Management, Configuration Management, and Software Development as shown in [Tab. 10](#).

Table 10: Profiles of the panel members

| Domain | No of experts | Overall knowledge/ Experience | CMMI/SPI knowledge & Experience |
|-------------------------------------|---------------|----------------------------------|------------------------------------|
| SPI Experts / CMMI Auditors | 2 | 20, 17 | 20, 16 |
| QA Managers | 2 | 19, 17 | 19, 15 |
| Project Managers | 2 | 20,15 | 15, 15 |
| Configuration Managers/ CM Auditors | 2 | 20,14 | 18,13 |
| Senior Software Engineers | 2 | 16,13 | 15,12 |

According to Khan et al. [16], researchers are free to establish their criteria. Experts were divided into 3 groups based on their experience/knowledge. Experts with less than 15 years of experience were classified as Junior, with more than 17 years of experience as Senior, and the rest were classified as Intermediate.

According to this criterion, the panel consisted of 4 senior, 2 junior, and 4 intermediate experts. The questionnaire was formulated based on the work of Keshta [3–6], and Niazi et al. [9] specifically to obtain the panel's opinion on the proposed WFMs. A summary of the experts' responses based on the 5-point Likert scale is presented in Tabs. 11–13. The Q-8 was an open-ended question that was used to collect feedback to improve the models.

Table 11: Summary of the responses to the proposed WFM for identification of configuration items

| | | <i>Question</i> | <i>Measure</i> | <i>SD/</i> | <i>D /</i> | <i>N /</i> | <i>A /</i> | <i>SA /</i> | <i>Mean</i> | <i>Rslt</i> |
|--|-----|--|----------------|------------|------------|------------|------------|-------------|-------------|-----------------------|
| | | | | "1" | "2" | "3" | "4" | "5" | | |
| Practice Satisfaction (Answer to RQ-A, B) | Q-1 | As per CMMI Ver. 1.3, the proposed model shall help to satisfy the SP-1.1 and contribute towards the achievement of SG-1 of CM-PA. | Freq %age | 0 0 | 0 0 | 1 10 | 5 50 | 4 40 | 4.3 | Strongly Agree |
| | Q-2 | How much our proposed WFM covers the SP-1.1 including Sub-SPs? (Fully Covered 5 – 1 Not Yet) | Freq %age | 0 0 | 0 0 | 2 20 | 3 30 | 5 50 | 4.3 | Fully Covered |
| User Satisfaction (Answer to RQ-C) | Q-3 | The proposed WFMs would prove useful for SSMEs. | Freq %age | 0 0 | 0 0 | 1 10 | 3 30 | 6 60 | 4.5 | Very Useful |
| | Q-4 | The use of the proposed WFM shall prove instrumental for the improvement of the software development process and contribute to the quality of products produced through it in SSMEs. | Freq %age | 0 0 | 1 10 | 1 10 | 4 40 | 4 40 | 4.1 | Agree |
| Ease of Learning & Use (Answer to RQ-D) | Q-5 | How clearly the said WFMs represents the SP-1.1 of SG-1 of CM-PA. | Freq %age | 0 0 | 0 0 | 1 10 | 8 80 | 1 10 | 4.0 | Clear |
| | Q-6 | In order to use the WFMs, how much knowledge of CMMI/SCM would be required? | Freq %age | 0 0 | 0 0 | 2 20 | 5 50 | 3 30 | 4.1 | Little |
| Implementability (Answer to RQ-E) | Q-7 | Our proposed WFMs can be implemented in SSMEs with little tailoring/tweaking. | Freq %age | 0 0 | 0 0 | 3 30 | 4 40 | 3 30 | 4.0 | Agree |

Table 12: Summary of the responses to the proposed WFM for establishing a CMS

| | | <i>Question</i> | <i>Measure</i> | <i>SD/</i> | <i>D /</i> | <i>N /</i> | <i>A /</i> | <i>SA /</i> | <i>Mean</i> | <i>Rslt</i> |
|--|-----|--|----------------|------------|------------|------------|------------|-------------|-------------|-----------------------|
| | | | | <i>"1"</i> | <i>"2"</i> | <i>"3"</i> | <i>"4"</i> | <i>"5"</i> | | |
| Practice Satisfaction (Answer to RQ-A, B) | Q-1 | As per CMMI Ver. 1.3, the proposed model shall help to satisfy the SP-1.1 and contribute towards the achievement of SG-1 of CM-PA. | Freq | 0 | 0 | 1 | 4 | 5 | 4.4 | Strongly Agree |
| | | | %age | 0 | 0 | 10 | 40 | 50 | | |
| | Q-2 | How much our proposed WFM covers SP-1.2 including Sub-SPs? | Freq | 0 | 1 | 1 | 1 | 7 | 4.4 | Fully Covered |
| | | | %age | 0 | 10 | 10 | 10 | 70 | | |
| User Satisfaction (Answer to RQ-C) | Q-3 | The proposed WFMs would prove useful for SSMEs. | Freq | 0 | 1 | 0 | 4 | 5 | 4.3 | Very Useful |
| | | | %age | 0 | 10 | 0 | 40 | 50 | | |
| Answer to RQ-C | Q-4 | The use of the proposed WFM shall prove instrumental to improve the software development process and contribute to the quality of the products produced through it in SSMEs. | Freq | 0 | 1 | 2 | 1 | 6 | 4.2 | Agree |
| | | | %age | 0 | 10 | 20 | 10 | 60 | | |
| Ease of Learning & Use (Answer to RQ-D) | Q-5 | How clearly the said WFMs represents the SP-1.2 of SG-1 of CM-PA. | Freq | 0 | 1 | 0 | 1 | 8 | 4.6 | Very Clear |
| | | | %age | 0 | 10 | 0 | 10 | 80 | | |
| | Q-6 | In order to use the WFMs, how much knowledge of CMMI/SCM would be required? | Freq | 0 | 1 | 1 | 4 | 4 | 4.1 | Little |
| | | | %age | 0 | 10 | 10 | 40 | 40 | | |
| Implementability (Answer to RQ-E) | Q-7 | Our proposed WFMs can be implemented in SSMEs with little tailoring/tweaking. | Freq | 0 | 0 | 2 | 2 | 6 | 4.4 | Strongly Agree |
| | | | %age | 0 | 0 | 20 | 20 | 60 | | |

According to the ERP results, experts believe that the models are easy to learn, effective in implementing the SPs, supportive in achieving SG-1, cover the sub-practices, improve the process, are very useful for industry software, contribute to the quality of the software produced, and applicable in SSMEs. However, as with other things, there is room for improvement in the proposed WFMs.

5.2 Case Studies Validation

To build trust, a case study was conducted in two Pakistani SSMEs that were willing to implement the WFMs. For reasons of confidentiality, cover names are being used. Briefs of the SSMEs are tabulated in [Tab. 14](#).

Table 13: Summary of responses to the proposed WFM for creating/releasing baselines

| | | <i>Question</i> | <i>Measure</i> | <i>SD/</i> | <i>D /</i> | <i>N /</i> | <i>A /</i> | <i>SA /</i> | <i>Mean</i> | <i>Rslt</i> |
|---|-----|--|----------------|------------|------------|------------|------------|-------------|-------------|-----------------------|
| | | | | <i>"1"</i> | <i>"2"</i> | <i>"3"</i> | <i>"4"</i> | <i>"5"</i> | | |
| Practice Satisfaction (Answer to RQ-A, B) | Q-1 | As per CMMI Ver. 1.3, the proposed model shall help to satisfy the SP-1.3 and contribute towards the achievement of SG-1 of CM-PA. | Freq %age | 0 0 | 0 0 | 1 10 | 1 10 | 8 80 | 4.7 | Strongly Agree |
| | Q-2 | How much our proposed WFM covers SP-1.3 including Sub-SPs? (Fully Covered 5 – 1 Not Yet) | Freq %age | 0 0 | 0 0 | 2 20 | 2 20 | 6 60 | 4.4 | Fully Covered |
| User Satisfaction Answer to RQ-C | Q-3 | The proposed WFMs would prove useful for SSMEs. | Freq %age | 0 0 | 0 0 | 0 0 | 6 60 | 4 40 | 4.4 | Very Useful |
| | Q-4 | The use of the proposed WFM shall prove instrumental to improve the software process and contribute to the quality of the products produced through it in SSMEs. | Freq %age | 0 0 | 1 10 | 1 10 | 3 30 | 5 50 | 4.2 | Agree |
| Ease of Learning & Use (Answer to RQ-D) | Q-5 | How clearly the said WFMs represents the SP-1.3 of SG-1 of CM-PA. | Freq %age | 0 0 | 0 0 | 0 0 | 3 30 | 7 70 | 4.7 | Very Clear |
| | Q-6 | In order to use the WFMs, how much knowledge of CMMI/SCM would be required? | Freq %age | 0 0 | 0 0 | 3 30 | 2 20 | 5 50 | 4.2 | Little |
| Implementability (Answer to RQ-E) | Q-7 | Our proposed WFMs can be implemented in SSMEs with little tailoring/tweaking. | Freq %age | 0 0 | 0 0 | 0 0 | 7 70 | 3 30 | 4.3 | Strongly Agree |

Table 14: Participant SMEs of the study

| Software SME | Size | Core expertise |
|----------------------------|------|---|
| Small Software Enterprise | 32 | Software development and provision of support to Pakistani Sugar Mills. |
| Medium Software Enterprise | 83 | Development of ERP for SMEs and the provision of maintenance support. |

The above-mentioned SSMEs were assessed by a CMMI expert as a readiness review of the three SPs of CM-PA and were found not ready. Two SSMEs agreed to participate in these case studies. A brief presentation covering the objectives of the study was given at the opening session for both the SSMEs. To assess the effectiveness of the proposed WFMs after implementation, the lead auditor in both SMEs performed SCAMPI type “C” and type “B” assessments for these SPs. The result of the assessments was encouraging. All three SEs (SP 1.1, SP 1.2, and SP 1.3) were considered “Fully Implemented” and their contribution to the satisfactory achievement of the said SG-1, i.e., “Establish Baselines” in both SSMEs. According to the lead auditor's statement, both SSMEs will easily produce a "Fully Implemented" score in SCAMPI type “A”. Feedback from participating professionals was also collected in the closing session.

5.3 Mitigation Actions

First, the closed-ended questions in the questionnaire may not have captured the true respondent’s feelings. An open-ended question was included to reduce the impact and capture the opinions freely. This added to the veracity of the response. Second, panel members may have interpreted the questions / WFM differently and answer accordingly. Due to the close connection, the questionnaire was taken from Keshta’s work [3–6]. This has been further refined by adding framework coverage at the sub-practice level and reviewed by another academician Third, the responses could be limited to the respondents' knowledge and experience. As part of building trust, experts with extensive industry experience participated in this research. The presence of world-renowned experts on the panel contributed to the effectiveness of the review process. Fourth, there may be a difference between the responses from Senior, Intermediate, and Junior experts. The P of Chi-Square (X2) test was found > 0.05 for $\alpha = 0.05$ and degree of freedom = 2 against the responses. It shows ignorable variation among the responses provided by the aforementioned three categories of experts. Fifth, the possibility that the usual literature review process may not have discerned relevant research work. As stated by Hossain et al. [17], this cannot be treated as a systemic omission. Finally, the results and conclusions may not be applicable in varied or typical environments. In addition to the EPR, case studies were conducted in the Pakistani SSME. Hence, the results can be generalized to the Pakistani SSME, however, more case studies should be carried out for external validity.

6 Proposed WFMs Novelty

The novelty of the models is tabulated in [Tab. 15](#) as under.

Table 15: The novelty of the WFMs in terms of features compared with earlier models for PAs

| Novelty features | Proposed models | Earlier models | | | | | | | |
|--|-----------------|----------------|------------|------------|------------|----------|------------|-----------|-----------|
| | | [3] Keshta | [4] Keshta | [5] Keshta | [6] Keshta | [7] Anum | [8] Bhatti | [9] Niazi | [10] Viva |
| Compliant to CMMI representation - Staged. | ☀ | ☀ | ☀ | ☀ | ☀ | | ☀ | ☀ | ☀ |
| Help to achieve objectives of SG-1 of CM-PA. | ☀ | ☀ | ☀ | ☀ | ☀ | ☀ | | ☀ | |
| Devised SP-wise. | ☀ | ☀ | ☀ | ☀ | ☀ | ☀ | | ☀ | |
| Satisfy the relevant SPs | ☀ | ☀ | ☀ | ☀ | ☀ | | | ☀ | ☀ |
| Cover the Sub-SPs. | ☀ | | | | | | | | |

(Continued)

Table 15 (continued).

| Novelty features | Proposed models | Earlier models | | | | | | | |
|--|-----------------|----------------|---------------|---------------|---------------|-------------|---------------|--------------|--------------|
| | | [3] Keshta | [4] Keshta | [5] Keshta | [6] Keshta | [7] Anum | [8] Bhatti | [9] Niazi | [10] Viva |
| Satisfy user. | ☀ | ☀ | ☀ | ☀ | ☀ | | | ☀ | |
| Easy to learn / easy to use. | ☀ | ☀ | ☀ | ☀ | ☀ | | ☀ | ☀ | |
| Provide Input / Output of the workflow. | ☀ | | | | | | | | ☀ |
| Provide the roles responsible for each step. | ☀ | ☀ | ☀ | ☀ | ☀ | ☀ | ☀ | | ☀ |
| Applicable to Software SMEs. | ☀ | ☀ | ☀ | ☀ | ☀ | | | | |
| Follow the ETVX Model. | ☀ | | | | | | | | |
| With relevant templates, forms & checklists. | ☀ | | ☀ | ☀ | ☀ | | | ☀ | ☀ |
| Associated process guide prepared. | ☀ | | | ☀ | | | | | |
| Address the overall CM-PA. | ☀ | | | ☀ | | | | | |

7 Conclusion

The development of a workflow model to achieve the SG-1 “Establish Baselines” of CM-PA at CMMI maturity level-II and its validation was the main objective of this study. For this purpose, five research questions (RQ-A ~ RQ-E) were formulated. Further WFMs were devised for all the three SPs contributing towards the establishment of baselines. The experts’ responses met the criteria listed. The results were further confirmed by conducting case studies. It is worth mentioning that the case studies have shown the ability of the Pakistani SSME to adopt the proposed models with slight changes to adapt to their contexts. Satisfactory comments from the participating organizations and experts speak well of WFMs and increase confidence in the evaluation results. During face-to-face discussions with participating professionals, it was found that they had no problem understanding / using models with related templates, forms, checklists, and process guides as supporting tools. WFM has been refined after several rounds of improvement taking into account the suggestions of scientists, specialists, and finally feedback from case study participants. This work should be continued to develop WFMs for other PAs for which the workflow models have still not been developed. Models should also be reviewed for external validity and future CMMI versions.

Funding Statement: The authors received no specific funding for this study.

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

References

- [1] G. Xu, H. Hu, P. Yu, J. Lv, P. Qu *et al.*, “Supporting flexibility of the CMMI process framework with a multi-layered process model,” in *Proc. Web Information System and Application Conf.*, Yangzhou, China, pp. 409–414, 2013.

- [2] CMMI Product Team, “CMMI for Development Version 1.3,” 2010.
- [3] I. Keshta, “A model for defining project lifecycle phases: Implementation of CMMI level 2 specific practice,” *Journal of King Saud University - Computer and Information Sciences*, vol. 10, no. 1, pp. 48, 2019.
- [4] I. Keshta, M. Niazi and M. Alshayeb, “Towards implementation of process and product quality assurance process area for Saudi Arabian small and medium-sized software development organizations,” *IEEE Access*, vol. 6, pp. 41643–41675, 2018.
- [5] I. Keshta, M. Niazi and M. Alshayeb, “Towards the implementation of requirements management specific practices (SP 1.1 and SP 1.2) for small- and medium-sized software development organisations,” *IET Software*, vol. 14, no. 3, pp. 308–317, 2020.
- [6] I. Keshta, M. Niazi and M. Alshayeb, “Towards implementation of requirements management specific practices (SP1.3 and SP1.4) for Saudi Arabian small and medium-sized software development organizations,” *IEEE Access*, vol. 5, pp. 24162–24183, 2017.
- [7] A. Tariq, S. A. Khan and S. Iftikhar, “Remapping of CMMI level-2 KPA’s for development process improvement of software-as-a-service (SaaS) cloud environment,” in *Proc. Int. Conf. on Open Source Systems and Technologies*, Lahore, Pakistan: IEEE, pp. 43–51, 2014.
- [8] M. W. Bhatti, F. Hayat, N. Ehsan, A. Ishaque, S. Ahmed *et al.*, “A methodology to manage the changing requirements of a software project,” in *Proc. Int. Conf. on Computer Information Systems and Industrial Management Applications*, Krakow, Poland: IEEE, pp. 319–322, 2010.
- [9] M. Niazi, C. Hickman, R. Ahmad and M. Ali Babar, “A model for requirements change management: implementation of CMMI level 2 specific practice,” in *Lecture Notes Computer Science (including Subserial Lecture Notes Artificial Intelligence Lecture Notes Bioinformatics)*. Vol. 5089, Monte Porzio Catone, Italy: LNCS, pp.143–157, 2008.
- [10] C. Vivatanavorasin, N. Prompoon and A. Surarerks, “A process model design and tool development for supplier agreement management of CMMI: capability level 2,” in *Proc. XIII ASIA PACIFIC Software Engineering Conf.*, Bangalore, India: IEEE, pp. 385–392, 2006.
- [11] A. Abran, J. W. Moore, R. Dupuis, R. Dupuis and L. L. Tripp, “Software Configuration Management,” in *Guide to the Software Engineering Body of Knowledge (SWEBOK), Ver 3.0. A Project of the IEEE Computer Society*, vol. 6, pp. 1–15, 2014.
- [12] Mary Beth Chrissis, M. Konrad and S. Shrum, “Configuration Management,” in *CMMI for development*, 3rd ed., Addison - Wesley, pp. 243–255, 2017.
- [13] M. Chaudhary and A. Chopra, “CMMI Design,” in *CMMI for Development – Implementation Guide*, India: Apress, 2, pp. 9–69, 2017.
- [14] G. O’Regan, “Configuration Management,” in *Introduction to Software Quality Assurance*, Ireland: Springer Springer Cham Heidelberg New York Dordrecht London, 5, pp. 89–99, 2014.
- [15] M. K. Kulpa and K. A. Johnson, “Understanding Maturity Level 2: Managed,” in *Interpreting the CMMI - A process improvement approach*, Boca Raton: Auerbach Publications, 5, pp. 59–79, 2008.
- [16] S. U. Khan, M. Niazi and R. Ahmad, “Empirical investigation of success factors for offshore software development outsourcing vendors,” *Institute of Engineering and Technology Software*, vol. 6, no. 1, pp. 1–15, 2012.
- [17] E. Hossain, M. Ali Babar and H. Y. Paik, “Using scrum in global software development: A systematic literature review,” in *Proc. Fourth IEEE Int. Conf. on Global Software Engineering*, Limerick, Ireland: IEEE, pp. 175–184, 2009.