Using Soft Systems Methodology Approach to Omprove Technical Solution Sub-process of Engineering Process in a SME: A case study

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Abstract

Small and Medium-sized Enterprises (SMEs) from different business sectors, that are certified by some standardization organizations, are increasingly prioritizing the process improvement to raise their product's quality. This paper proposes a qualitative research that will consider the question 'how are the means of optimizing change in SME's engineering process certified by CMMI, identified and modeled consistently, using Soft Systems Methodology (SSM)?'. The author analyzed problematic cases related with technical sub-process, compared them with real world activities, modelled the potential changes and monitored the improvements for technical solution sub-process in accordance to case study. It is hoped that this research will inform future research for process improvement in any organizations by using SSM.

Keywords: Engineering design process, Process improvement and soft systems methodology.

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Introduction and Background

Small and Medium-sized Enterprises (SMEs) uses process approach, that are usually adapted from some standards and/or guidelines, and improving them is important for the product's quality of SMEs. Process Improvement (PI) is generally thought as an important approach for increasing organizational performance by improving the effectiveness and efficiency of business processes. PI activities that are related to organizational level changes are directly interested in the role of humans. The parameters to sustain the process improvement, named as Continuous Improvement (CI), are based on involvement of management, improvement of the goals, performance criteria of processes, measures and being provided with sufficient resources.

Design processes are the main part of the products that are designed and developed because of aiming the improvement of the product. There are many different definitions for design phases in the literature (Howard, T. J., et al. 2008) and so the definition of design process can be changeable from organization to organization in accordance to their product's spectrums. Mainly, the core phases of design process can be defined as 'planning and task clarification', 'conceptual design'; 'embodiment design' and 'detailed design' after comparing existing definitions of the design process in the literature (Pahl G. et al., 2011).

Some guidelines like Capability Maturity Model Integration (CMMI), International Organization for Standardization (ISO) can be preferred by organizations to build their process definitions and activities for their business. These guidelines generally address the development activities to whole lifecycle of the products or services. In CMMI level 3, the design processes are divided into five sub processes labeled as 'Requirements Development', 'Technical Solution', 'Product Integration', 'Verification' and 'Validation' (Software Engineering Institute, 2010).

Although there are many process improvement methodologies in the literature that can be applicable to design process in an organization, choosing the most suitable methodology has the most important manner for the organizations. At this point, there can be a need about merging or modifying the existing improvement methodologies to provide the desired outputs or outcomes for process improvement (Rashid, O. A. and Ahmad, M. N., 2013). In CMMI, process improvement is mainly focused on three critical dimensions named as 'people', 'process/methods' and 'tools/equipment'. The selection of improvements is based on mainly understanding the aimed benefits and predicted costs of deploying related improvements to the existing processes (Software Engineering Institute, 2010).

Design process and its sub-processes can be assumed as a system because of the system definition in the literature. It is defined as "a regularly interacting or independent group of items forming a unified whole" in the Merriam-Webster dictionary (Merriam Webster, 2017). On the other hand, systems thinking approach has some similarities with system because of containing three kinds of things labeled as 'elements', 'interconnections' and 'a function or purpose' (Meadows, D. H., 2008). While the one

segment of systems thinking, hard systems thinking, is mainly related with well-defined technical problems; the other, soft systems thinking, is concerned with fuzzy ill-defined situations involving human beings and cultural considerations (Checkland P., 2000). Hard systems thinking is not enough to address the real world problems and provide approaches for solving them. Soft systems thinking is generally preferred to address real world problems and Soft Systems Methodology (SSM) is an action oriented approach that deals with ill structured problems and provides some suggestions to solve them (Zhou, H., 2011).

Data Collection

The required data for study is collected from engineering team in the SME by applying semi-structured interviews. Primarily, a meeting was organized to specify the focal points of engineering process and its sub-processes (see Appendix A). In the following periods, the meetings are individually organized to perform semi-structured interviews for TS sub-process (see Appendix B). Semi-structured interviews include the data gathered from personal interviews, face to face meetings, observations and other traditional methods used for the examination ofengineering department. The aims of interviews and face to face meetings is getting detailed information and observations about definitions of existing processes, the problems or problematic cases faced while applying them and the outputs of TS sub-process when is applied on a project. The data collection and analysis approach is shown on Figure 1.

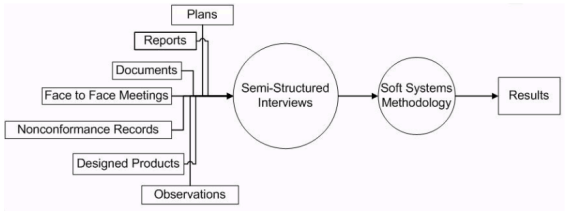

Figure 1: The data collection and analysis model.

Engineering Process in the SME

The engineering process of the SME that is certified by CMMI has four sub-processes named as 'Requirements Development', 'Technical Solution' (TS), 'Integration' and 'Verification and Validation'. The organizaiton chart of engineering design process is given on Figure 2. Also there are four support processes in the organization that serve all processes. These support processes are labeled as 'Configuration Management', 'Risk Management', 'Measurement, Analysis and Improvement' and 'Quality Assurance' (see Appendix A).

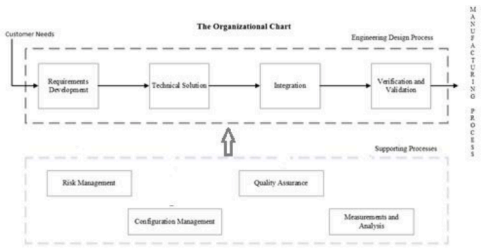

Figure 2: The organizational chart.

During data collection, the required data that is used to define problematic cases is obtained from the practitioners of engineering processes and its sub-processes. While performing group interviews and face to face meetings, the data is also collected about support processes and their effects on the technical solution sub-process. TS sub-process is used for implementing the technical solution of the project that is defined with given requirements by customers. Configuration Management process from support processes is used for traceability of requirements and product trees. The other support process, Quality Assurance mainly concerns with conformity of designed product to defined requirements and uses the produced documents to assure conformity. Measurement, Analysis and Improvement process is used to measure the performance criteria of the engineering design process, analyzing them (if requires) and define improvements in accordance to measurement of them. After completion of engineering design process and its sub-processes, the project activities continue with manufacturing processes.

Methodology

Stage 1: Enter Situation Considered Problematic

According to Soft Systems Methodology (SSM), everything can produce problematical situations that perceived differently by the various participants because of their worldviews. Therefore, every problematical issue should be defined by using roles and interrelations of involved people in social, cultural and political context.

In this paper, the information is gathered to improve TS sub-process by evaluating the various roles and interrelations between employees, employers, process owners and project team in social and personal context. Employees and process owner activities are expressed with Root Definition that is also used to create Conceptual Models. Conceptual Model enables to question problematical issues in the process and provides knowledge about how to improve it. Addressed changes or improvements about sub-process can be implemented to solve problematical issues but the implementation of defined improvements is outside the scope of this study.

Stage 2: Express the Problem Situation for Technical Solution Sub-Process

The group interviews are implemented with design teams that have resposibility on technical analysis of requirements and detailed information is gathered about technical solution sub-process (see Appendix B). The focus groups' rich picture is given on Figure 3. The main activities of this sub process are as follows; deciding to which requirements are critical, product arhitecture definition, configuration items definition, categorization of hardware, software and physical interfaces, purchasing hardware components/materials, development of hadrware and software configuration items, definition of the tests for hardware and software configuration items, determination of test environments and reviews.

The requirements and test scenarios are derived from requirement development sub-process. The crititical requirements are specified and the design specifications for them are defined. The schedule, cost, performance are evaluated to implement these activities. The functionality is defined in the concept of derived requirements and its arhitectural structure is also defined. While this definition, the configuration items are addressed in accordance

to two category named as software configuration items and hardware configuration items.

After definition of design configuration items, the interfaces of design are determined as physical and/or hardware/software. If the iterfaces' definitions do not meet all of the defined requirements, requirements changes are realized and also impact analysis is prepared. The related documents are updated to reflect the changes. If the interfaces are enoough for defined requirement, the process continues with development of hardware and software configuration items.

Before starting the development activities of hardware configuration items, purchase activities are completed. During supply process of the required component, hardware designers work on definition of circuit diagrams. Circuits diagrams are drawn on a tool, then they are manufactured. Some verification activities can be implemented on these diagrams but not for all circuit diagrams. After the completion of supply process, the hardware design is implemented and also test environments related with configuration items are defined. On the other hand, the software configuration items are developed and also its test environments are defined. Coding is implemented. Sometimes, special test enviroments can be required by customer and so these request are taken into consideration by design team.

While implementation of these activities that are mentined above, the all information is recorded on design document. The primary and critical design reviews are implemented for design document, hardware configuration items and software configuration items by designers. After critical design review, technical solution sub process is completed.

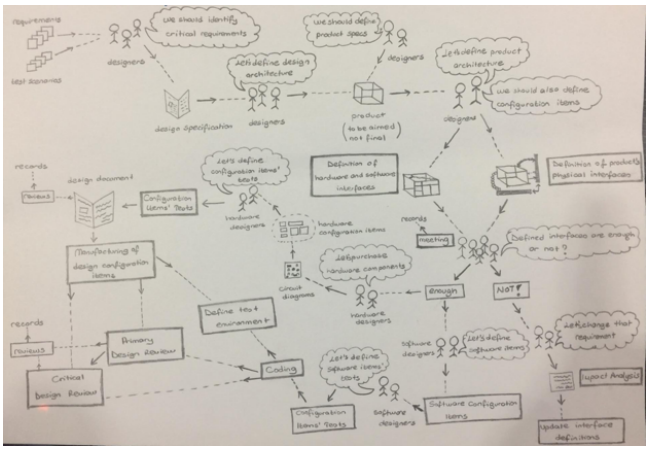

Figure 3: Rich picture for technical solution sub-process.

Stage 3: Formulate Root Definition of Relevant Systems

The root definition is used to describe the activity system that needed to be created in order to improve the defined situation in part 4.2 and CATWOE rule is used. It is also the basis for building conceptual model of the system at the following part.

Customers (C): The customers of this tranformation can be seen as a group of interested parties. These parties can be defined as the project team, the owners of the TS sub-process.

Actors (A): The people concerned with the transformation are the employees of the design group.

Transformation (T): The transformation is required to add or redefine some process steps that can be more applicable for employees. There is a defined sub process related with this case in the organization but the defined steps in the process do not cover every activities that are implemented by employees. New additional activities should be defined to have a well defined process approach.

Worldview or Weltenshauung (W): There are some worldviews to consider in this case and they can be aligned as employees, the related sub process owners and indirectly end users. Employees and the process owners are also participants of the process. Sometimes, end users can have some request in the project's concept to change the existing sub process practices. The employees are the most relevant view in achieving the necessary transformation.

Owners (O): The owners can be thought as people or institutes that creates TS sub-process definition and also provides some standarts, guidelines about how it can be aplied for any organizations. The SME's processes are certified by CMMI Institute.

Environment (E): The environment for change can be defined as office, work area, infrastructure and related tools. Office, work area and infrastructure are provided by organization. Tools are selected by employees and then organization supply the desired tools.

Table 1: The root definition statement.

Root Definition Statement:
Redefining of technical solution sub-processes, certified by CMMI, to improve the existing process, to become more applicable by employees in an environment that have enough infrastructure.

Stage 4: Build Conceptual Models for Technical Solution Sub-Process

The conceptual model that is defined on Figure 4, identifies technical solution sub-process that can be performed by related hardware/software designers during design life cycle. It provides detailed information about design activities after completion of requirement management sub-process. It covers required activities for design and documentation of produced knowledge to reuse them later. Also this process provides convenience about requirement traceability from contract level to detailed design level.

Stage 5: Compare Conceptual Model with Real World for Technical Solution Sub-Process

The conceptual model that is determined (refer 4.4) facilitates a consideration of the technical analysis of design in order to find ways to improve it. After determining a conceptual model, the real world activities as illustrated in the rich picture are compared with the conceptual model. The details are given on Table 2.

Stage 6: Define Proposed Changes for Technical Solution Sub-Process

The proposed changes that will guide to Engineering Design Department to improve the technical solution sub process are addressed as follows:

Determination of critical design requirements and their alternatives. While specify the critical design requirements and their alternatives, the methods and approaches that are used to verify and validate them, should be also taken into consideration.

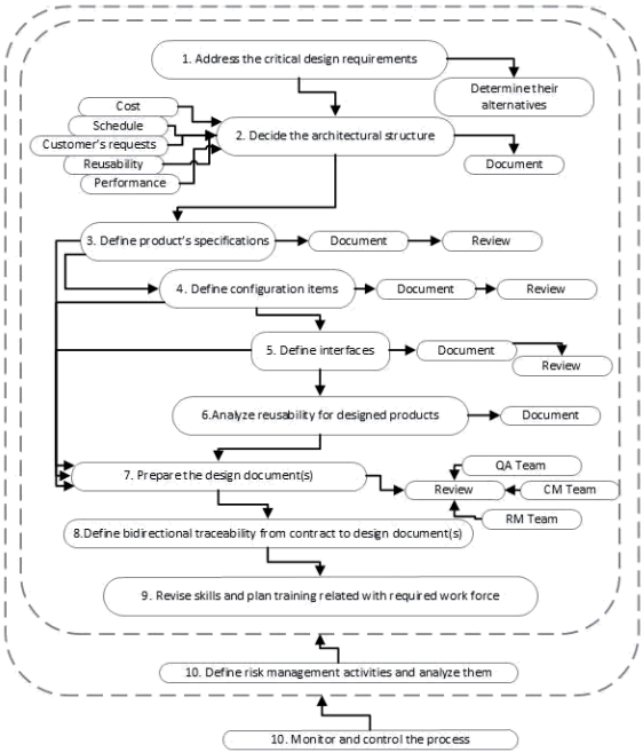

Figure 4. Conceptual model for technical analysis of design.

The decision mechanism for architectural structure. An instruction or policy should be prepared for this purpose and the criterias that are used for decision, should be defined in it. The required criterias are defined on conceptual model as cost, schedule, performance, reusability and customer's requests. Generally, comparison approach is preferred for decision and the details can be defined on decision instruction/policy.

The definition of product's specification in accordance with the requirements that are defined on requirements management sub-process. This definition shoul include product's circuit diagrams, product trees and (if requires or there is any risk) product's alternatives. After definition is completed, this product's sepcification should be documented. It should be also reviewed by design team.

The determination of configuration items as software and hardware configuration items by taking into consideration the existing infrastructure. At this phase, evaluation of infrastructure has an importance for design implementation. If there is any deficiency, the project schedule can delay. The defined configuration items should be documented and reviwed by design team.

The definition of interfaces as physical, hardware and software and then documentation of them. The documentation of interfaces has an importance for integration phase. Therefore, documentation activity should be performed for every design project. Review of the documentation should be performed by design team.

The reusability analysis for components/architectural structure/product's specification and documentation of them. It can be said that reusability is an important manner for the organization because of serving similar porducts to the market. Therefore, it can be said that reusability can provide benefits to the organization. The reusability analysis should be performed for every projects.

Table 2. The comparison between conceptual model and real world for technical analysis of design.

Conceptual Model Activities (Technical Analysis of Design)	Real World Activities
Address the critical design requirements by using derived requirements from requirements management sub-process and then determine their alternatives.	The critical design requirements are addressed by using the outputs of requirements management sub-process but the alternatives of them are not defined in the concept of design project. If a problem occurs, the alternatives are evaluated, otherwise not.
Decide the architectural structure consisting cost, schedule, performance, reusability and customer's request parameters, document it.	While deciding to arhitectural structure, cost, schedule and performance parameters are evaluated but not documented. Reusability and customer's request should be added into parameters and also their evaluations should be documented.
Define the product's specifications, document and review them between team members.	The product specifications are defined but not documented and reviewed between team members.
Define the configuration items, document and review them between team members as software and hardware configuration items after being sure that the infrastructure enables to implement related configuration items.	Generally,the configuration items are defined then the infrastructure is evaluated. This can cause loss of labor. On the other hand, the defined configuration items are not documented and reviewed.
Define the interfaces as physical, hardware and software, document and review them between team members.	The interfaces are defined as physical, hardware and software. Generally they are documented in design document.If there is a request by customer, they are documented as separately. The review activities are coordinated in the concept of the design document.
Define and analyze reusability for the designed products and then document them.	The reusability depends on the designer's experience.There are no record about reusability for existing projects.
Prepare the design document and review it with project team that contains related responsibilities (Quality Assurance Team, Configuration Management team and Risk Management team)	Design document is prepared and then reviewed by desgin team but the other authorities (Quality Assurance Team, Configuration Management team and Risk Management team) are not involved.
Define bidirectional traceability from contract to the design document that can cover the technical solution activities.	It is not applied for all design projects.
Revise skills and plan training related with required work force.	Tranings are planned but generally existing skills are not evaluated.
Define risk management activities, analyze and document them.	There is no formal documentation for risk management activities in the concept of techical solution sub-process.
Monitor and control the process.	Performance criterias are defined but there is no measuring, monitoring and controlling mechanism.

The generation of design document covering the information about architectural structure, products' specifications, configuration items, interfaces and reusability analysis. After documentation process, this document should be reviewed by not only design team but also responsibles of Quality Assurance, Configuration Management and Risk Management. Additionally, it can be

suggested that interface documents should be prepared as separately from design document to be more functional.

The selection of a tool for bidirectional traceability from contract to design document and adding required information about this approach to the policy or instruction that will be defined.

The definition of a new method for revision of employee's skills and registration of them.

The definition of a new policy or instruction that should guide to risk management activities for technical solution sub process. There are some critical points such as purchasing required components, defining alternative architectural structures and configuration items etc.If there is any problems about the defined risks, it can cause delays on schedule, over cost, low performance etc.

The implementation of monitoring and controlling activities for technical solution sub-process by auditing and defining a method and/or performance criterias that can be measured.

Conclusion

This study was set up to investigate the role of SSM in improving technical solution sub-process for the SME that is certified by CMMI. The participants in semi-structured interviews have similar background at their education levels. The most of proposed changes are based on lack of some documentation about activities performed or not. There are documentation needs about definition of bidirectional traceability, revision of employee's skills, review mechanism, decision mechanism, reusability analysis, risk management activities, checklist and non-conformances' records. These improvements can be implemented into design group with the supports of employees, process owners and managers. In additionally, quality assurance team can have a supportive role for these improvements by checking or controlling the expectations of some standardization organizations.

During this study, it is proved that SSM is a fruitful in identifying various approaches for improvement. Interviews with employees, process owners and managers revealed that there are extensive lists of options for improvements in design process and its' sub-processes. The most of improvements, that are suggested, are addressed during interviews by questioning as to why things are processed the way they are. Therefore, this methodology can be applicable to other processes of the SME.

From our experience, SSM can be used for information management and business analysis that can be concluded as process improvement or defining lacks of existing processes because of focusing on human beings involvement, human situations and cultural considerations. It enables the participants to engage in a continuous learning process that enhance the willingness to collaborate in achieving the desired outcomes or outputs. It also helps to identify process areas that need to be improved and also define the weaknesses where hard systems thinking approaches have been unable to do so.

References

Checkland, P. (2000). Soft Systems Methodology: A Thirty Year Retrospective. Systems Research and Behavioural Science, 17, 11–58. https://doi.org/10.1002/1099-1743(200011)17:1+<::AID-SRES374>3.0.CO;2-O

Howard T. J., Culley S. J. and Dekoninck E. (2008) " Describing the creative design process by the integration of engineering design and cognitive psychology literature", Design Studies Vol 29 (2008) 160e180 doi:10.1016/j.destud.2008.01.001 160

Meadows, D. H. (2008). Thinking in Systems: A Primer. White River Junction, VT: Chelsea Green Publishing. ISBN-13: 978-1603580557.

Merriam Webster. (2017). Dictionary by Merriam-Webster: America's most-trusted online dictionary. Merriam-Webster, Incorporated. Retrieved from https://www.merriam-webster.com/

Pahl, G., Beitz, W., Feldhusen, J., & Grote, K.-H. (2011). Engineering design: A systematic approach (K. Wallace & L. T. M. Blessing, Trans. 3rd ed.). Darmstadt: Springer.

Rashid O. A., Ahmad M. N. (2013). "Business Process Improvement Methodologies: An Overview". Journal of Information System Research Innovation, 5: 45-53

Software Engineering Institute. (2010). CMMI for Development, Version 1.3. Carnegie Mellon University, (November), 482. https://doi.org/CMU/SEI-2010-TR-033 ESC-TR-2010-033

Zhou, H. (n.d.).Soft Systems Methodology (SSM) in Information System Analysis. RetrievedJanuary2011,from http://www.umsl.edu/~sauterv/analysis/6840_f03_papers/zhou/

Appendices

Appendix A: Interview Design

Target Interviewee: Design process owners, designers and their managers.
Nature of Interview: Group interview, face to face meetings.
Interview Type: Semi-Structured
Methods of Appointment: Personal Contact, Personal Visits, Emails and Telephone.
Focal Points: The focal points that are given below, are determined from acquaintance meetings. The first meeting is coordinated to include participation of employees' representatives, process owners and the managers of the design engineers. The general knowledge about design process and Technical Solution (TS) sub-processes is obtained from this meeting. The shared data is mainly categorized as follows. (The detailed contents of conservation about TS is also given at Appendix B)

- Process Documents
  - Flow Diagrams of Process and Sub-Processes
  - Procedures and Policies
- Engineering Design Life Cycle
  - Planning of Engineering Design Process
  - Effort and Cost Estimation
  - Risk Identification and Categorization
  - Requirement Traceability
- Architectural Structure of Design
- Interface Identification and Management
  - Detailing the Design Requirements as Hardware and Software
  - Reviews of Related Documents, Plans and Records
- Required Training
- Noncompliance Issues
- Configuration Management Records
  - Traceability between Process and Sub-Processes Design Baselines
  - Process and Sub-Processes Evaluation
  - Process and Sub-Processes Audits

Appendix B: Meeting (The Evaluation of Technical Solution Sub-Process)

"…..Requirements and their test scenarios are defined at requirements management sub-process…..the requirements can be categorized as low level and high level....There is need to define the critical requirements……The design specifications are defined based on the performed activities at requirements management sub-process….the design architecture should be defined…..Product specifications are generally defined before integration sub-process……. The defined design architecture is used to define product architecture…...The configuration items are determined based on defined product's architecture…..The physical interfaces are determined….. The hardware and software interfaces and configuration items are specified……The qualification of interfaces are evaluated by related designers but there is generally no records related with it……If the interface definition are not enough, some changes should be implemented on requirements…….. the requirements changes triggers the schedule delays…….The qualification of hardware and software interfaces are evaluated……During evaluation phases, there are many meetings within designer not project team……..The required data, infrastructure, components are provided to implement hardware and software items…….The required tests are defined for designed hardware and software components……The coding activities are performed by software design engineers…..The integration of software and hardware is a very critical issue for integration phase but the interfaces between them are thought during technical sub-process……All activities that are performed at this phase are documented by designers……the design document are prepared and reviewed…..The review activities are generally implemented within design team……. If customer have a request about reviewing design document, the document are shared with customer via project team…..The review activity is generally recorded….The test environments are also defined for software, hardware configuration items and their interfaces…..the defined test environments are also important for integration, verification and validation phases…….There is two review steps named as primary design review and critical design review at the procedure and policy.……These review activities are important for the baselines of requirements that are used for the following sub-processes….."