Hybriding CMMI and Requirement Engineering Maturity & Capability Models

Applying the LEGO Approach for Improving Estimates

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Abstract: Estimation represents one of the most critical processes for any project and it is highly dependent on the quality of requirements elicitation and management. Therefore, the management of requirements should be prioritised in any process improvement program, because the less precise the requirements gathering, analysis and sizing, the greater the error in terms of time and cost estimation. Maturity and Capability Models (MCM) represent a good tool for assessing the status of a set of processes, but an inner limit of any model is its scope and approach for describing a certain issue. Thus, integrating two or more models with a common area of focus can offer more information and value for an organization, keeping the best components from each model. LEGO (Living EnGineering prOcess) is an approach projected for this purpose. This paper proposes a LEGO application hybridizing a 'horizontal' model (a MM containing processes going through the complete supply chain, from requirements right through to delivery, e.g. CMMI or ISO 12207/15504) with a few specific 'vertical' models (MMs with focus on a single perspective or process category, e.g. TMMi or TPI in the Test Management domain, P3M3 and OPM3 in the Project Management domain) for Requirement Engineering.

1 INTRODUCTION

One of the latest neologisms from the last 5 years is 'glocal'(Swyngedouw, 1997), which refers to the ability to "*think* globally and *act* locally". Cultural differences among countries should be taken into account more and more when designing processes, particularly as very interesting ideas may arise from a comparison among different practices. For instance, when comparing Western and Eastern worlds and behaviours, Western people 'act', Eastern people 'think' (a bit more) before acting (Hassan et al., 2010) (Luo, 2008) (Chang, 2010). But observing both perspectives and attitudes, it is possible to represent it as a sort of 'yin-yang', complementing each other (Stawicki, 2008). Thus, there is never a better idea, but different shades to be considered when (re)designing a process and/or a technique.

Estimation is one of the core processes in any organization. According to the Webster-Merriam dictionary, it is "1. a judgment or opinion about something; 2. the act of judging the size, amount, cost, etc., of something : the act of estimating something; 3. a guess about the size, amount, cost, etc., of something". PMBOK defines estimation as "a quantitative assessment of the likely amount or outcome. Usually applied to project costs, resources, effort, and durations and is usually preceded by a modifier (i.e., preliminary, conceptual, feasibility, order-of-magnitude, definitive)" (PMI, 2008).

However, estimates often have a higher error rate than expected, by running a RCA (Root-Cause Analysis) for detecting issues, it is possible to remove issuing surrounding requirements. The top-10 of estimation "deadly sins" (McConnell, 2002) (McConnell, 2006) can be a valid starting point for improving it, noting how much the missing (or the low quality) of requirements and its related historical data as well their granularity level could largely impact on the estimation process. Using again CMMI-DEV elements, Project Planning (PP)

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process area – where estimation is run – in the 'Related Process Areas' includes also Requirement Management (RM) and Requirement Development (RD) for the management of requirements; PP SP1.2 affirms that "The estimates should be consistent with project requirements to determine the project's effort, cost, and schedule". It's the same when using the SPICE (ISO/IEC 15504) language, dealing with MAN.3 (Project Management) for estimates and ENG.1 (Requirements Elicitation) plus ENG.4 (Software Requirement Analysis) (Buglione et. al., 2012)..Thus, there is a huge need for any organization to first reinforce the Requirement Management process (in a broader sense, not strictly in the CMMI terms because it's a ML2 process area), starting from elicitation and analyzing (RD – Requirements Development, ML3) throughout requirements management.

But what's the problem? What does not currently exist?

The aim of this paper is to propose a LEGO (**L**iving **E**n**G**ineering pr**O**cess) application for the Requirements Engineering (RE) area, matching together different RE processes using a four-step process, in order to obtain a comprehensive process to be applied in an organization, which could enable better estimates to be achieved.

The paper is organized as follows: Section 2 proposes a series of specific requirements management maturity models and frameworks, for extracting any possible element of interest (EoI) for reinforcing a typical Requirements Engineering (horizontal) process. Section 3, summarizes the LEGO approach, with its main elements and four-step process. Section 4, shows the deployment of LEGO to the Requirements Management process, joining the CMMI-DEV RD process area with the EoI from the previously examined RE models/frameworks. Finally, Section 5 provides some conclusions and the next steps for this work.

2 REQUIREMENT ENGINEERING: SOME MATURITY & CAPABILITY MODELS (MCM)

During the '90s the 'maturity models mania' started (Copeland, 2003) and now many 'something-maturity-model(s)' exist in many application areas and domains, and this is also the case for (software) RE. Table 1, presents some Maturity Models in the RE arena that can represent potential "vertical" models to be integrated into a consolidated and well known "horizontal" model such as CMMI-DEV (SEI, 2010) or SPICE (ISO/IEC 15504) (ISO, 2007).. The specific processes to be involved would be respectively: RD (Req. Development) and RM (Req. Management) for CMMI_DEV and ENG.1 (Req. Elicitation) and ENG.4 (Software Design) processes for SPICE. For each of the models we present: its representation types, number of MLs, process architecture type and further comments/notes.

Some comments about those RE models that could be useful for the LEGO analysis:

- A general trend in RE is to propose staged models more than continuous ones → suggesting a 'standard' way to progress maturity within an organization more than focusing upon each single RE process. This provides interesting information should be considered when re-modelling these models into a target model according to its process architecture.
- No particular architectural elements have been introduced/modified against well-known horizontal models, differently than in other application domain (e.g. see P3M3 (OGC, 2006) and OPM3 (PMI, 2008) in the Project Management) → there is evidence that many of those models are still maturing and evolving (e.g. (Beecham et al., 2003) and (Solemon et al., 2009) have deployed only details for ML2).
- Documentation should be provided to fully describe the requirements and project scope → this is a point of contact with Quality Management Systems (QMS) such as ISO 9001 or 20000-1, this is typically stressed less in CMMI constellations (see also the results from Mutafeljia & Stromberg's mapping (Mutafelija, 2008)) but thus is not the in SPICE related models (including a specific process on Documentation: SUP.7). Another interesting related issue concerns the quest for reducing requirements volatility (e.g. REAIMS) and defining a taxonomy of requirement attributes for properly managing them by interest groups and/or techniques (e.g. REPM), for instance, making a clear distinction between functional vs. non-functional product requirements from the outset. This is a relevant issue in the FSM (Functional Size Measurement) community, where there is often – at the practical level – a misconception about the roles and relevance of NFR (Non-Functional Requirements) against FUR (Functional User Requirements) in the estimation process, where NFR are typically underestimated because not properly evidenced (and sized) from the requirement elicitation phase.

Table 1: Some Requirement Engineering Maturity Models/Frameworks.

Model/ Framework	Repr. Type	ML (#)	Architect-Type	Comments/Notes
IBM RMM (Heurmann, 2003) (Sehlhorst, 2007)	Staged	6 [0-5]	Level-based	---
IAG RMM (IAG, 2009)	Staged	6 [0-5]	Matrix-based	6 dimensions (process, practices & techniques, deliverables, technology, organization, staff competency)
PRTM CRMM (Hepner, 2006)	Staged	4 [0-3]	Level-based	---
BTH REPM Gorschek et al, 2002) (Gorschek, 2011)	Continuous		Process-based	7 processes Variable number of sub-process areas per process
REAIMS Process MM (Sommerville, 2005)	Staged	3 [1-3]	Process-based	8 process areas and 66 practices (basic, intermediate, advanced)
R-CMM (Beecham et al. 2005) (Beecham et al., 2003)	Staged	5 [1-5]	Process-based	'Processes' = Practices (e.g. 20 'processes' at ML2) - Adaptation of GQM for deriving practices
R-CMMi (Solemon et al., 2009)	Staged	5 [1-5]	Process-based	'Processes' = Practices (e.g. 20 'processes' at ML2) - Adaptation of GQM for deriving practices using the CMMI process architecture

The allowed choices for the "Architectural Type" column are: **Level**-based (high-level depth, generic description of needed actions per ML), e.g. (Ambler, 2010); **Matrix**-based (mid-level depth, indication of a series of improvement drivers with a specific text per each cell), e.g. (ISO, 2009); **Process**-based (low-level depth, with a consistent process architecture and repeatable elements per each defined process), e.g. (SEI, 2010)(ISO, 2007).

3 EXPERIENCING LEGO TO REQUIREMENT ENGINEERING

3.1 The LEGO Approach

Recently we proposed a common-sense approach, called **LEGO** (**L**iving **E**n**G**ineering pr**O**cess) (Buglione et al., 2011) for stimulating organizations to improve their own processes, taking pieces (such as the real LEGO bricks) from multiple, potential information sources to be integrated to form a unique, reinforced picture for a particular process or set of processes. The starting point – for this paper – is that any model/framework can represent only a part of the observed reality, not all of its possible views, simply because it needs to represent one single viewpoint at a time. Thus, through handling similar elements from different sources, we can hopefully find more 'fresh blood' for improving the organizational processes.

LEGO has four main elements, as shown in Figure 1:

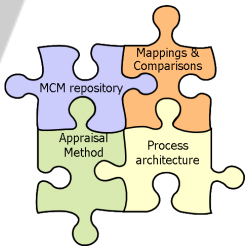

Figure 1: The four elements of the LEGO approach.

1. a 'Maturity & Capability Models' (MCM) repository (www.gqs.ufsc.br/mcm), from relevant processes or MMs (meaning also the other dimensions – not yet the process dimension) can be identified;
2. knowledge about the process architecture of each model, for understanding how to transform desired elements from a certain model into the target format, especially when considering that the source models may have different architectures that need to be integrated into a single model;
3. mapping(s) & comparisons between relevant models, in order to understand the real differences or the deeper level of detail from 'model A' to import into 'model B';
4. a process appraisal method (PAM) to be applied on the target BPM (Business Process Model).

LEGO has also a related four-step process:

1. **Identify your informative/business goals**: clearly identify your needs, moving from the current BPM version and content.
2. **Query the MCM repository**: browse the MCM repository, setting up the proper filters in order to obtain the desired elements (processes; practices; etc.) to be inserted in the target BPM.
3. **Include the selected element(s) into the target BPM**: include the new element(s) in the proper position in the target BPM (e.g. process group, maturity level, etc.).
4. **Adapt & Adopt the selected element(s)**: according to the process architecture of both process models (the target and the source one), the selected elements may need to be adapted, tailoring such elements as needed.

3.2 Applying LEGO to Requirement Engineering

One of the main requirements for improving estimates is to reinforce the management of requirements from an overall viewpoint, from their elicitation through to the day-to-day management.

The focus of this work is exclusively on external models as opposed to actual (living and active) organizational practices, so that any reader can easily access to the original sources and fully understand the LEGO process, that could (eventually, if interested) be replicated in his/her own organization through forward moving from their existing organizational Business Process Model (BPM). Our aim is to show how to hybridize ideas for obtaining a better and more comprehensive final result. Thus, we list the preconditions, process and main results from the application of the LEGO process to the Requirements Engineering (RE) domain, in order to propose a better RE process that may be applied in an organization:

1. **Identify your informative/business goals**: improve the estimation capability and results by a refinement in the overall management of requirements (business, technical):
2. **Query the MCM repository**: in this paper we consider CMMI-DEV RE processes (RD; RM) as the baseline for working upon, adding eventual practices from the other RE models/frameworks listed in Table 1. After a detailed analysis, we discarded the IBM RMM, proposing only a high-level staged path with no detailed elements, and focus on the remaining ones. Table 2 proposes the list of potential elements of interest (EoI) to consider for improving CMMI processes on RE.

Table 2: RE Maturity & Capability Models (MCM): Elements of Interest.

Model/ Framework	Elements of Interest (EoI)
IAG RMM	• Technology: the introduction of workflow environments for easily sharing information for keeping requirements could be useful → CMMI-DEV RD GP2.3 (Elaboration section in Part 1) • Staff competency: suggested the introduction of Bloom's levels as informative notes for all GP 2.5, not only for those two PAs
PRTM CRMM	• Level 1: link between product and customer requirements, using e.g. QFD (quality function deployment) → it could be introduced also in CMMI-DEV RD SP 3.4, not only in SP 2.1 (as currently done) for closing the analysis
BTH REPM	• RE.SI (Stakeholders and Req. Source Identification) → more specific practice to be added about Requirement Elicitation to CMMI-DEV RD SG1 • RE.GA.a2 (Qualify and Quantify Quality Requirements) → currently missing a more clear and direct link with CMMI-DEV PP SP 1.2 • DS.GA.a2 (Define Requirement Attributes) → currently less stressed (e.g. FUR vs NFR for FSM/FPA – Function Point Analysis, as requested in CMMI-DEV PP, SP 1.4
REAIMS Process MM	Basic practices: • 3.1 Define a standard document structure: missing, could be added in CMMI-DEV RD SG1, stressing the need for having an organizational 'standard' for comparing different types of requirements, having impact also on planning (different roles, productivities and schedules for different activities → PP SP 1.4). Again, it'd help also PP SP 1.2 because it'd address better the • 3.8 Make the document easy to change → criteria for writing better requirements, could be stressed more in CMMI-DEV RD SG1 / RM SG1, SP 1.3 • 6.2 Use language simply and concisely → criteria for writing better requirements could be added as a note for CMMI-DEV RD SP 1.2, sub-practice #1 Advanced practices: • 9.8 Identify volatile requirements: suggested to introduce the concept of 'volatility' also in the RD process definition by an informative note (e.g. "…verifying the new need will not be yet addressed by a formalized requirement…", with a link to RM, SP 1.3), → see also R-CMMi P20 process, same issue
R-CMM	• ML2: P19: Agree and document technical and organisational attributes specific to project → CMMI-DEV RD deals with customer and product requirements, not addressing with further informative notes about which could be possible 'constraints' such as those ones from the analysis of organizational attributes → reinforce RD SP 1.1
R-CMMi	• ML2: P20: Institute Process to Maintain Stability within Project → always about the need to minimize 'volatility', in terms of management → same comment than for REAIMS practice 9.8

3. **Include the selected element(s) into the target BPM**: looking at the analysis of potential EoI in Table 2. The main improvements/suggestions seem to be mainly associated with the RD process, rather than the RM process. Table 3

Table 3: CMMI-DEV RD: suggestions for improvements.

CMMI-DEV v1.3 RD process	Suggested Improvements
SG 1 Develop Customer Needs	• Introduce a new SP 1.0 about Stakeholders Identification and Engagement. Rationale: reinforce current formulation, before running SP 1.1. Nowadays, stakeholder engagement is the sub-practice #1 within SP 1.1. • Insert a note about possible standards (de jure/de facto) that could be consulted/useful for a better application of RD process (e.g.. (AccountAbility, 2011)).
SP 1.1 Elicit Needs	• Introduce a sub-practice about the definition of requirement attributes, inserting a cross-link with PP SP 1.2 for the classification of work products (by attribute) to be sized. • Modify the current WP into: 'results of requirement elicitation activities **by entity and attribute**' (see previous comment)
SP 1.2 Transform Stakeholders needs	• Rephrase and make more general sub-practice #2: not only functional vs. quality (non-functional) attributes, but possibly establish all valuable, possible requirements taxonomies and classifications for the organization (by other criteria)
SG 2 Develop Product Requirements	• Introduce a note within the SG text about the need and relevance of define a (standard) document structure (in terms of 'documentability') and suggest – as informative note – some possible criteria to follow and appraise (e.g. readability, simple and concise language for writing requirements, etc.).
SP 2.1 Establish Product and Product components	• Sub-practice #3: refine the Example box, do no mention generic quality attributes, but be more specific about requirement classifications (e..g ISO/IEC 14143-1:1998 → functional, quality, technical) → cross-link with PP 1.2 about attributes for sizing.
SP 2.2 Allocate Product Components	• ---
SP 2.3 Identify Interface Requirements	• ---
SG 3 Analyze and Validate Requirements	• ---
SP 3.1 Establish Operational Concepts and Scenarios	• ---
SP 3.2 Establish a Definition of Required …	• ---
SP 3.3 Analyze Requirements	• ---
SP 3.4 Analyze Requirements to Achieve Balance	• Introduce an informative note about the possible usage of QFD matrices also here, not only for eliciting and determining requirements in SP 2.1
SP 3.5 Validate Requirements	• ---

Table 3: CMMI-DEV RD: suggestions for improvements (cont.).

GP 2.3 Provide Resources	• General: stress the need and opportunity from workflow environments for an easier sharing of information among stakeholders, whatever the (CMMI) process • Specific (RD Elaboration): specific need because RD is the starting process for gathering needs to be translated into solutions
GP 2.5 Train People	• General: introduce the application of the six Bloom's cognitive levels (Bloom et al., 1956) for classifying knowledge (see also IEEE SWEBOK – www.computer.org/swebok) • Specific (RD Elaboration): add 'stakeholder engagement' (AccountAbility, 2011) and 'requirement sizing' (ISO, 2011)
GP 2.8 Monitor and Control the Process	• Specific (RD Elaboration): introduce at least one measure about the effectiveness of RD SG1 goal (e.g. % of proposed vs validated requirements)

shows how our suggestions were introduced in the current RD process, describing a new possible improved process that may be mapped against your own QMS internal process(es) covering that subject.

4. **Adapt & Adopt the selected element(s)**: after adapting the original RD process, as shown in the previous table, it should be mapped against the related QMS internal process covering that subject. Since many organizations adopt an ISO management system (e.g. ISO 9001:2008), a cross-check for validating potential improvements from the design phase could be achieved through re-applying the related mapping document to their own internal process (e.g. using the N/P/L/F – Not/Partially/Largely/Fully achieved ordinal scale from CMMI or SPICE). In our case, moving from CMMI-DEV, it could use Mutafeljia & Stromberg's mapping document (Mutafelija, 2008) as a basis. In this paper, our focus was limited to only the design phase. However, a case study with the application of the hybrid-RD process will be included in a future paper.

4 CONCLUSIONS & NEXT STEPS

Requirements are the first step for a project and if they are not clearly and unambiguously defined this can increase the probability that project estimates will be incorrect because the project/activity scope has not been clearly documented. Even, if there are many existing requirements management models and frameworks , each model represents only one possible view of the inner reality that would be

captured and reused: the '*one size doesn't fit all*' motto could be rephrased as '*one model doesn't fit all*'. Thus, at least 2 (or more) models/frameworks should be considered for improving your own processes (whatever they are), in the areas/issues needed.

In order to cope with this need, we recently proposed **LEGO** (**L**iving **E**n**G**ineering pr**O**cess) as an open approach for improving the processes of a business process model (BPM), based upon the comparative analysis of the process architecture and elements of several concurrent models within a certain domain. Since estimation is one of the key processes for determining the success of an organization, we applied LEGO to Requirements Engineering, with the aim to improving the CMMI-DEV RD (Req. Development) process by integrating it with other requirements engineering maturity models. The final result was the design of a more encompassing hybrid-RD process that could help organizations to improve their estimates from the beginning of the value chain.

In the future, we will apply this hybrid-RD process to real case studies, proposing it as the meta-model to be used for the performing the initial gap analysis against the organizations' BPM related processes as part of an improvement initiative.

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APPENDIX - LIST OF ACRONYMS

BPM	Business Process Model
CL	Capability Level
CMMI	Capability Maturity Model Integration
CMMI-DEV	CMMI for Development
ENG.1	Requirement Elicitation
ENG.4	Sw Requirement Analysis
IEC	Int. Electrotechnical Commission
ISO	Int. Organization for Standardization
LEGO	**L**iving **E**n**G**ineering pr**O**cess
MAN.3	Quality Management process
MCM	Maturity & Capability Model
ML	Maturity Level
MM	Maturity Model
NFR	Non-Functional Requirement
OPM3	Organizational Project Management Maturity Model
P3M3	Portfolio, Programme, and Project Management Maturity Model
PAM	Process Assessment Model
PMBOK	Project Management Body of Knowledge
PMI	Project Management Institute
PP	Project Planning
PRM	Process Reference Model
QMS	Quality Management System
RCA	Root-Cause Analysis
RD	Requirement Development
RE	Requirement Engineering
REAIMS	**R**equirements **E**ngineering **a**daptation and **im**provement for **s**afety and dependability
REPM	Requirements Engineering Process Model
RM	Requirement Management
SEI	Software Engineering Institute
SPICE	Software Process Improvement Capability dEtermination (ISO/IEC 15504)
TMMi	Test Maturity Model Integration
TPI	Test Process Improvement