

Supporting Time Planning Aligned with CMMI-DEV and PMBOK

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Abstract— Software projects often fail, because they are not adequately managed. The establishment of effective and efficient project management practices especially with respect to time management still remains a key challenge to software organizations. Striving to address these needs, “best practice” models, such as, the Capability Maturity Model Integration (CMMI) or the Project Management Body of Knowledge (PMBOK), are being developed to assist organizations in improving project management. Yet, so far there does not exist a unified model focusing on the context of small and medium enterprises (SMEs). Therefore, this paper presents a generic model for time planning aligned with CMMI and PMBOK. In order to facilitate its application in practice an open-source tool (dotProject) has been enhanced and evaluated by project management specialists. The results of this research are expected to facilitate the adoption of time planning practices in SME contributing positively to their competitiveness.

Keywords- time planning; PMBOK; CMMI; dotProject.

I. INTRODUCTION

Many software development projects still have problems to be delivered on time, within budget and with the complete scope defined [1]. In this context, one of the most important processes in the project management life cycle is time planning [2]. The aim of time planning processes is to deliver the project on time [2].

One of the reasons for these problems is a lack of project management, which indicates that establishing effective and efficient project management practices is still a challenge for many organizations [3].

As an attempt to improve this situation, “best practices” models have been developed to guide organizations interested in improving the project management process. This includes the CMMI-DEV (Capability Maturity Model Integration for Development) that guides the improvement and appraisal of a software organization’s processes [4]. This model, although comprehensive, covers also “best practice” for project management. Another more specific “best practice” model for project management is the PMBOK (Guide to the Project Management Body of Knowledge) [2], which describes the life cycle of managing a project and the respective knowledge areas. Such maturity models, e.g., the CMMI, also indicate the importance of improving the project management process, as it is typically one of the first processes indicated to be improved associated to maturity level 2.

However, a large part of the IT market is composed of SMEs [5]. Many of these organizations typically struggle to implement these models [6]. Thus, in order to facilitate the

adoption of best practices for time planning in SMEs, this work presents a generic model for a time planning process aligned with PMBOK and CMMI and customized to the characteristics of SMEs. In order to support the application of the model in practice we also enhanced one of the most popular open-source tools – dotProject – in conformance with the proposed model. The use of tools is important for SMEs as it can support and partially automate steps, increasing efficiency and improving the maturity of the process [7].

We first present the background to our research in Section 2. Analyzing and comparing both models, we map the respective best practices developing a unified model with respect to time planning as presented in Section 3. Section 4 describes the proposed generic model for time planning, demonstrating how processes/practices recommended by reference models could be applied to SME context. The tool enhancement and evaluation is presented in Section 5. Finalizing the paper, we discuss the results.

II. BACKGROUND

This section presents the key concepts with respect to project management and especially time planning and introduces PMBOK and CMMI.

Project management is the application of knowledge, skills, tools and techniques to project activities to meet their requirements [2]. A project is a temporary endeavor undertaken to create a unique product, service, or result. To achieve the goals defined in the project, knowledge, techniques and tools are applied that constitute project management. The project management life cycle is composed of five process groups [2] (Figure 1):

- **Initiation:** performed to initiate a new project or phase and obtain the authorization for its realization.
- **Planning:** performed to establish the project goals and scope and to define the actions necessary to ensure that the project meets its objectives.
- **Execution:** processes related to the execution of the project during which the work is carried out to complete the activities defined in the project plan.
- **Monitoring and controlling:** performed to monitor, review and adjust the project performance and progress, realizing corrective actions.
- **Closing:** performed to finalize all project activities in a formal way.

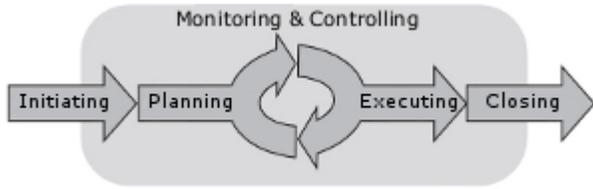


Figure 1 - Project management life cycle [2]

Orthogonal to this, project management processes are divided into 9 knowledge areas [2]: Integration, Scope, Time, Cost, Quality, Human Resource, Communication, Risk, and Procurement.

According to PMBOK, time planning requires processes to:

- Define Activities: a process to define the actions to be executed in order to produce project deliverables.
- Sequence activities: a process to define the logical dependencies between project activities, and also to define its execution order.
- Estimate activities resources: plan human and non human resources needed to execute project activities.
- Estimated activities duration: estimated the total time period needed to conclude the project activities. To do so it is necessary to know the activities scope, the resources available and others restrictions.
- Develop schedule: this process defines that each project activity has its own start and end dates, effort, duration, and resources estimated, as well the activity dependencies. Often it is represented as a Gantt chart.

A. CMMI

The Capability Maturity Model Integration (CMMI) provides a framework for improvement development process for software products and services. It describes the best practices associated to activities covering the life cycle of products from conception to delivery and maintenance [4]. Currently, there exist 3 different constellations: CMMI for Development (CMMI-DEV), CMMI for Acquisition (CMMI-ACQ) and CMMI for Services (CMMI-SVC). Here, due to our scope on software development, we focus on the CMMI-DEV constellation [4]. Its purpose is to help organizations improve their development and maintenance processes for both products and services. Within the CMMI Product Suite, a project is defined as a managed set of interrelated resources which delivers one or more products to a customer or end user. A project has a definite beginning and typically operates according to a plan. Such a plan is documented and specifies what is to be delivered or implemented, the sources and funds to be used, the work to be done, and a schedule for doing the work.

CMMI constellations are basically composed through two dimensions: process areas and capability/maturity levels. CMMI-DEV v1.3 defines 22 process areas grouped in four process categories. In this research, we focus mainly on project planning (PP) process area associated to maturity level 2, due to our specific focus on time planning practices

that are supported by this process area. Specific practices related to time planning are:

- PP/SP 1.1 Estimate the Scope of the Project: practice related to project activates definition, derived from project Work Breakdown Structure (WBS).
- PP/SP 1.2 Establish Estimates of Work Product and Task Attributes: Accomplish estimations for work products size and task attributes, as estimated duration, start and end dates.
- PP/SP 2.1 Establish the Budget and Schedule: The budget is out of the scope of time planning, but the schedule is included, involving activities duration estimation and sequencing activities.
- PP/SP 2.4 Plan for Project Resources: Estimate for each project activity the human and non human resources and its quantities for accomplishing the activity.
- PP/SP 1.4 Determine Estimates of Effort and Cost: The cost estimation is out of scope of time planning, but the effort estimation is included. Estimation effort means the number of work periods that are needed to realize an activity.

III. PMBOK AND CMMI PRACTICES UNIFICATION

As a first step into the direction of a harmonized support aligned with both models, we analyzed and compared the best practices as required by both models for time planning and mapped them (TABLE I – column 3 and 4). The work is based on earlier research of the authors on unifying and harmonizing CMMI-DEV v1.2 (PP, PMC, SAM) and PMBOK processes [10], which has been revised and updated with respect to the new current version of CMMI-DEV v1.3.

Based on this we defined a set of Unified Best Practices (UBPs) covering completely both models (TABLE I – column 1 and 2).

TABLE I - UNIFIED BEST PRACTICES FOR TIME PLANNING

UBP	Description	CMMI-DEV v1.3:2010	PMBOK 4ed:2008
P1	Define Activities	PP/SP 1.1 Estimate the Scope of the Project	6.1 Define Activities
P2	Establish Estimates of Work Product and Activity Attributes	PP/SP 1.2 Establish Estimates of Work Product and Task	-
P3	Sequence Activities	PP/SP 2.1 Establish the Budget and Schedule	6.2 Sequence Activities
P4	Plan for Project Resources	PP/SP 2.4 Plan for Project Resources	6.3 Estimate Activity Resources
P5	Estimate Activity Durations	PP/SP 2.1 Establish the Budget and Schedule	6.4 Estimate Activity Durations

P6	Estimate Effort	PP/SP 1.4 Determine Estimates of Effort and Cost	
P7	Develop Schedule	PP/SP 2.1 Establish the Budget and Schedule	6.5 Develop Schedule

IV. GENERIC PROCESS MODEL

In accordance to the defined unification of both models and taking into consideration characteristics and needs of SMEs, we propose a generic process model for time planning. The proposed model (Figure 11) is defined using the formal notation SPEM which is maintained by OMG [8].

The model is composed of artifacts, processes, and tools (techniques and methods). The sequence of the processes is defined as shown in Figure 11. For each process inputs and outputs artifacts are defined. Each process is detailed in next sections.

A. Define activities

This process goal is to identify and document the work that has to be done to build the project deliveries. Project activities are identified based on the defined work packages in the WBS (*Work Breakdown Structure*). For each of the work packages one or more activities are identified – representing the work that has to be done to create the respective results. A technique to execute this process is named decomposition [2]. If existent, an organizational process model can also used as a basis.

B. Sequence activities

Sequence activities is the process related to identifying and documenting the logical relationships between project activities.

A technique used to define activities’ dependencies is PDM (Precedence Diagram Method) [2]. It is based on a network diagram to represent all project activities and its dependencies (Figure 2).

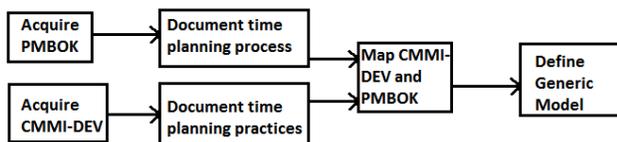


Figure 2 - Precedence diagram method

C. Establish Estimates of Work Product and Activity Attributes

This process aims at the estimation of the size and complexity of work packages. It is also related to the estimation of activity attributes as start and end dates, effort and duration.

The work package size is used to estimate the software dimension in a quantitative way. Size and complexity can be estimated using several units, for instance, size could be

estimated using lines of code, function points or use case points [2]. It is considered an initial parameter, to perform other estimations as effort and cost.

D. Plan for Project Resources

This process aims at the estimation of the resources (people, equipments, etc.) and its quantities that will be needed to execute the project activities. Resources are typically estimated based on specialized opinion based on the roles defined in the organizational chart.

E. Effort estimation

The effort is the amount of work needed to execute an activity. Effort is typically estimated in terms of person-hours, person-months etc. Well accepted techniques for the estimation process include either the usage of historical data (often not available in organizations with an immature process such as many SMEs) or consensus-based techniques including wideband delphi [11] or planning poker [12].

F. Estimate activities duration

This process aims at estimating the duration of the activities. Typically the duration is estimated in periods of work (e.g.: hours or days) that are needed to conclude it. Several techniques typically adopted include:

- Expert opinion: Specialists provides their estimations for the duration of activities based on previous experiences.
- Analogue estimation: The duration of a similar activity, which was executed in a previous project to estimate the duration of this new activity, is used.
- Parametric estimation: The estimation is realized in a quantitative way. Making arithmetic calculus based on the amount of work and team productivity.

G. Schedule development

The schedule development is the process that determines the planned dates for start and ending each project activity. To develop the schedule in an optimized way, techniques typically adopted include:

- Schedule network analysis: It indicates the project duration. By applying this technique it is possible to know the project end date on worse and better cases.
- Critical path method (CPM): It identifies all activities which can’t suffer any delay. A sequence of activities which can’t suffer delay are called critical path. When some critical path activity suffers delay, the entire project will be delayed.

The main output for this process is the project schedule. The schedule typically is as a Gantt chart (Figure 3).

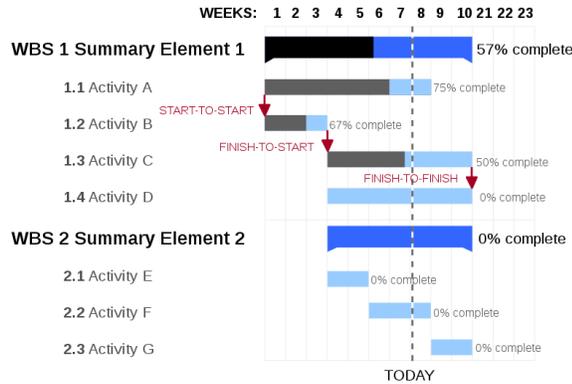


Figure 3 - Project schedule

V. TOOL SUPPORT

To facilitate the application of the proposed generic model in practice, tool support has been developed. Due to financial restrictions in the context of SMEs, we opted for enhancing one of the most popular free open-source tools - dotProject. One of the main reasons for choosing this tool, it is that new features can be built and installed as add-on modules using the tool's development framework. This possibility to adapt the tool usually is not available in commercial tools, e.g., ms project (microsoft.com/project) or primavera (oracle.com/primavera).

A. DotProject

DotProject [13] is a web-based tool for project management. It supports user management, projects listing, hierarchical task definition and schedule visualization (Gantt), client management, besides offering features such as contact list, file repository and calendar (Figure 4). The software supports MySQL or ADOdb databases and has been developed using PHP. Released in 2000, its current version is 2.1.6. It is an open-source system, published under General Public License (GPL), which means it can be customized and redistributed once the GPL is maintained.

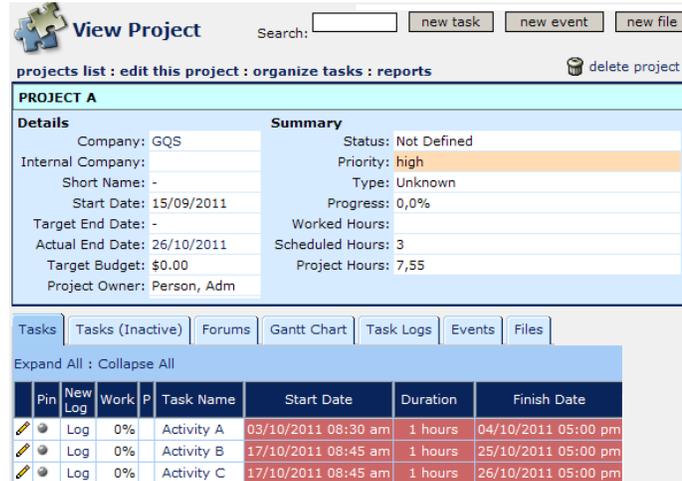


Figure 4 – dotProject

The current core version of dotProject does already partially support the time planning process. In a first step we analyzed the degree of support provided in conformance with the set of unified best practices (including PMBOK and CMMI). To assess the degree of support provided by dotProject in relation to each time planning UB (TABLE I) we defined a 4-point ordinal rating scale as presented in TABLE II.

TABLE II - RATING SCALE [3]

Rating	Description
-	Does not provide any support.
*	Offers basic support, covering less than half of the UB.
**	Covers more than half of the UB.
***	Offers a complete set of elaborate functionalities for this UB.

As a result, we identified that basically all required best practices are supported at least in a very simple way (TABLE III), yet with exception to the process “Develop Schedule” all processes need to be enhanced to provide full support.

TABLE III - DOTPROJECT TIME PLANNING SUPPORT [14]

UBP [3]	Description	dotProject version 2.1.6
P1	Define Activities	**
P2	Establish Estimates of Work Product and Task Attributes	*
P3	Sequence Activities	**
P4	Plan for Project Resources	**
P5	Estimate Activity Durations	**
P6	Estimate Effort	*
P7	Develop Schedule	***

VI. ENHANCEMENTS TO DOTPROJECT IN ORDER TO SUPPORT THE GENERIC MODEL

Based on the identified shortcomings as presented in TABLE III, we enhanced dotProject in alignment with PMBOK and CMMI [14]. This section presents the step by step modifications made.

Besides evolving functionality directly related to time planning processes, we also identified the need to develop features related to other processes, but required as inputs to the time planning processes, such as defining a WBS, so far not supported by dotProject core modules.

A. Defining Work Breakdown Structure (WBS)

In order to allow the systematic registration of the project scope in form of a WBS, we developed a new functionality, which supports the representation of project's

WBS (Figure 5). The created WBS is used as input to the process Define Activities.

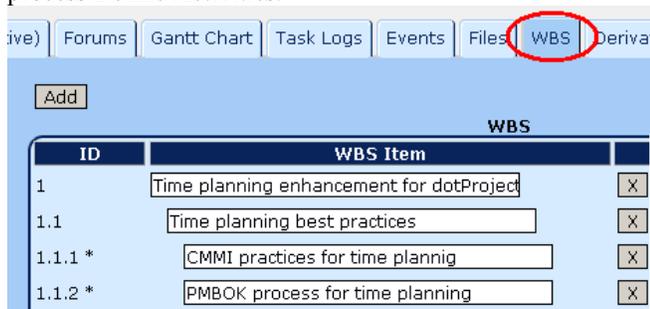


Figure 5 - Defining WBS

B. Defining activities based on work packages

Following PMBOK, activities are defined by decomposing work packages into activities. To support this process, we developed a functionality that visualizes the defined WBS and supports the addition of activities for each of the defined work packages (Figure 6).

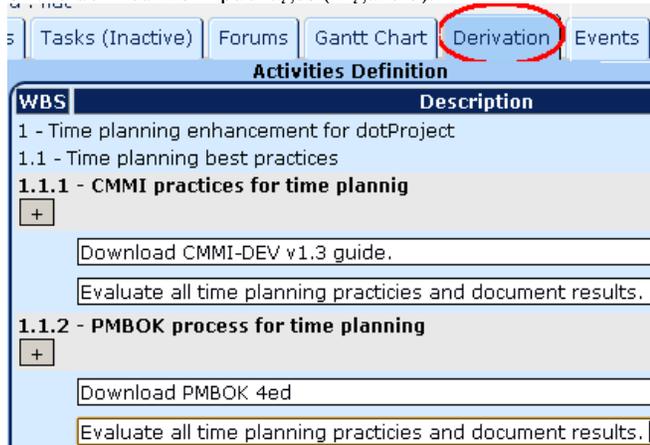


Figure 6 - Defining project activities by work package

C. Sequence activities

The core implementation of dotProject allows the identification of relationships between activities, but not clearly.

Yet, in order to provide a better support we developed a feature that supports the definition of the dependencies between activities using the Precedence Diagram Method (PDM) in a graphical way visualizing project activities linked as a network.

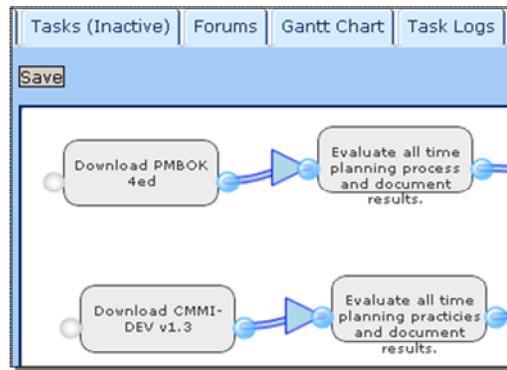


Figure 7 - Sequence activities

D. Creating a meeting minute for estimation sessions

In accordance with the proposed process, estimations are made based on consensus, e.g., in planning poker sessions. In this context, tools support is basically required in terms of documenting how the estimates have been determined. Therefore, a new feature has been added to the tool, which supports the registering of a meeting minute for estimation sessions. As part of this meeting minute it is possible to document what has been estimated, when the session has taken place, who participated, as well as details with respect to the estimates (Figure 8).

Figure 8 - Estimation minute form

The determined estimates (size/complexity) can be registered with respect to the specific work package. For each activity effort and/or duration estimates can be registered (Figure 9).

Estimations					
WBS	ID	Activity	Effort	Duration	Resources (roles)
1 - Time planning enhancement for dotProject					
1.1 - Time planning best practices					
1.1.1 - CMMI practices for time planning Size: 7 UCP					
	114	Download CMMI-DEV v1.3	1	Hours	1 System analyst
	115	Evaluate all time planning practices and document results	3	Hours	1 System analyst

Figure 9 - Activities estimations details

For each activity, the tool also supports the estimation of the required resources by selecting required roles from the organizational chart.

E. Schedule development

To support schedule development a new functionality has been developed based on the Critical Path Method (CPM). It can be executed after all activities have been sequenced and their efforts have been estimated. This method calculates the start and end dates for activities based on project start date, sequence of activities, and estimated efforts. As a result, the tool also automatically creates a Gantt chart with this information in order to visualize the schedule (Figure 10).

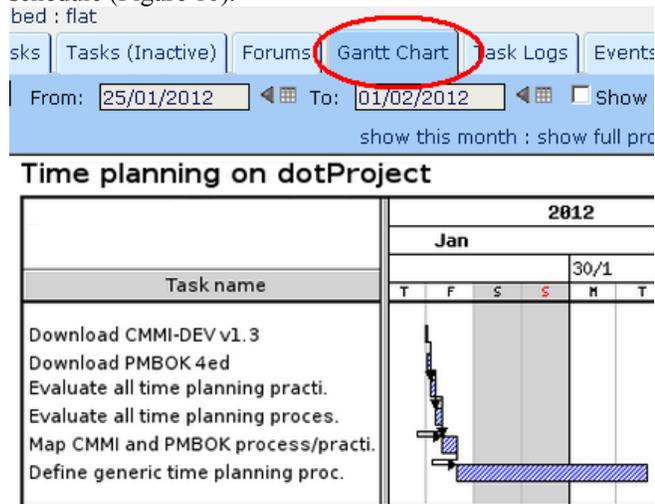


Figure 10 - Gantt chart

In this respect several enhancements have been developed in order to facilitate the application of the generic time planning process in practice, partially even automating steps as far as possible.

VII. EVALUATION

As part of our research we also evaluated the proposed generic model and the developed tool enhancements. Our evaluation goals are:

- Goal 1: Evaluate, if the enhancement of dotProject is helpful to support time planning in software projects in SMEs.
- Goal 2: Analyze if the generic process model is complete, consistent, and adequate for SMEs.
- Goal 3: Identify the strong points and the improvements points of proposed solution.
- Goal 4. Compare the degree of alignment of the enhancements of dotProject with dotProject v2.1.6.

With respect to the identified evaluation goals, we performed two types of studies. With respect to goals 1-3 we performed an expert panel and with respect to goal 4 we repeated the heuristic evaluation done in the beginning.

A. Expert panel

Adopting the GQM method [5], we decomposed these goals into questions and metrics. The required data has been collected through an expert panel capturing the opinion of software project management experts. Therefore, a questionnaire has been designed, transforming the metrics into affirmations and using a 5-point scale (1 – strongly disagree to 5 – strongly agree) (TABLE V).

TABLE IV – QUESTIONNAIRE ITEMS

Goals	Questions
Goal 1	1.1 I consider the evolution of dotProject useful for activity definition.
	1.2 I consider the evolution of dotProject useful for activity sequencing.
	1.3 I consider the evolution of dotProject useful for the documentation of size/effort/duration estimations.
	1.4 I consider the evolution of dotProject useful for the documentation of resources estimation documentation.
	1.5 I consider the evolution of dotProject useful for schedule development.
	1.6 The enhanced version of dotProject completely supports time planning.
	1.7 The enhancement of dotProject is consistent.
	1.8 The evolution of dotProject is adequate to support time planning on SME.
Goal 2	2.1 I consider the generic process model for time planning adequate for SMEs.
	2.2 I consider the generic process model for time planning consistent.
	2.3 The generic process model for time planning covers time planning completely to realize time planning.
Goal 3	3.1 What are the main strengths you observed?
	3.2 What are the main improvements suggestions?
	3.3 Do you have any other comment?

The evaluation was realized by project management specialists in SME context. The participants were chosen based on their availability to participate in a short period of time.

The specialists invited to join the experiment, did so in a voluntary capacity.

Beside the questionnaire the experts received an evaluation guide that explains the generic process model (Figure 11), and also demonstrates the enhanced tool

functionality (Section V). The experts have been asked to follow the process model using dotProject on a time planning example and afterwards to respond the questionnaire.

B. Results

The evaluation was realized during the months of May and June 2012. We invited 34 experts, selection based on their software project management expertise and their short term availability. In total, we received 10 responses, representing a response rate of 29%. The invitation was sent by e-mail, containing the evaluation guide and the link to the online questionnaire.

Analyzing the experts’ responses, TABLE V shows the median for each of the items.

TABLE V – MEDIANS PER ITEM/GOAL

Questionnaire item	Median
Goal 1	
1.1 I consider the evolution of dotProject useful for activity definition.	5
1.2 I consider the evolution of dotProject useful for activity sequencing.	5
1.3 I consider the evolution of dotProject useful for the documentation of size/effort/duration estimations.	4
1.4 I consider the evolution of dotProject useful for the documentation of resources estimation documentation.	4
1.5 I consider the evolution of dotProject useful for schedule development.	5
1.6 The enhanced version of dotProject completely supports time planning.	4
1.7 The enhancement of dotProject is consistent.	5
1.8 The evolution of dotProject is adequate to support time planning on SME.	4
Goal 2	
2.1 I consider the generic process model for time planning adequate for SMEs.	4
2.2 I consider the generic process model for time planning consistent.	4
2.3 The generic process model for time planning covers time planning completely to realize time planning.	4

B. Heuristic evaluation

As in the beginning of the enhancement of dotProject, we repeated the same heuristic evaluation with respect to the defined UBPs. The results are presented in TABLE VI.

TABLE VI - EVALUATION OF ENHANCEMENTS ON DOTPROJECT [14]

UBP [3]	Description	dotProject version 2.1.6	Enhanced version dotProject
P1	Define Activities	**	***
P2	Establish Estimates of Work Product and Task Attributes	*	***
P3	Sequence Activities	**	***
P4	Plan for Project	**	***

	Resources		
P5	Estimate Activity Durations	**	***
P6	Estimate Effort	*	***
P7	Develop Schedule	***	***

Among the project management open-source tools, dotProject is considered the one that most provides support to the best practice models [3]. The enhancements made in this work, added several important features, such as, definition of WBS, and activities creation based on decomposition technique [2], clearly distinguishing the concepts of project work package and project activity. The sequence of the activities using the PDM [2], and also the estimations registration are important improvements to support the development of project schedule, which is the main output of time planning process.

C. Discussion

Analyzing the presented results, we can identify a very positive feedback in general.

In relation to Goal 1, we observed a strong tendency for total agreement of the experts regarding the questions whether the tool enhancement is helpful – all medians are between 4 and 5.

With respect to Goal 2, the experts also agreed that the proposed generic process model is complete, consistent, and adequate for SME. Experts agreed on all items with a median of 4. Yet, as no strong agreement has been obtained on average we can also identify that some further small improvements could be carried out.

With respect to Goal 3 the experts highlighted as strengths principally the harmonization between CMMI and PMBOK aligned to one single process model for time planning. One expert also stressed very positively the enhancement of an open-source tool to support the model. Several experts highlighted that the explicit separation, between work packages and project activities is a very useful feature, as most project management tools don’t separate these concepts clearly.

In respected with Goal 4, we identified that the enhancement in fact has been done in correspondence with the PMBOK and CMMI and that with the enhancement made a full support in conformance with these models is provided.

D. Threats to validity

The evaluation we performed of course represents only a starting point. There can be identified several threats to validity of the results due to limitations of the evaluation for practical reasons. One threat is the small number of software project managers involved. As this number does not by any means provide statistical representativeness. At this point of time, we also involved only experts from Brazil. This of course limits strongly the generalization of the obtained results.

Another threat to validity can be the definition of metrics and data collection instruments. Yet, adopting GQM to systematically derive the metrics and questionnaire issues, such a threat may be small.

Another issue to be considered is the fact that dotProject in itself presents several usability problems and is therefore not very intuitive to be used.

Thus, evaluators may have found difficulties in the executing of the exemplar time planning tasks not related to the feature itself but due to general usability problems.

VIII. CONCLUSION AND FUTURE WORK

This work intends to facilitate the adoption of systematic time planning in SMEs in conformance with the PMBOK and CMMI. Therefore, we unify best practices from both models, propose a generic process model for time planning customized to the context of SMEs and enhance a free open-source tool to support the process in practice.

A first evaluation provided a very positive feedback, stressing principally the tool enhancement as one of the strengths of the work.

Based on the obtained feedback, we are currently improving the process model and the dotProject evolution.

The evaluation we have performed focused on the application of generic process model in SMEs, and it was evaluated by project manager experts in SMEs context. There is a possibility that this model also could be applied in large organizations, but for that a new evaluation focused in this context should be applied.

As future work, we are amplifying the scope of our work aiming at the coverage of the complete project management life cycle, including e.g., monitoring & control, as well as all relevant knowledge areas (scope, cost, risks, etc.).

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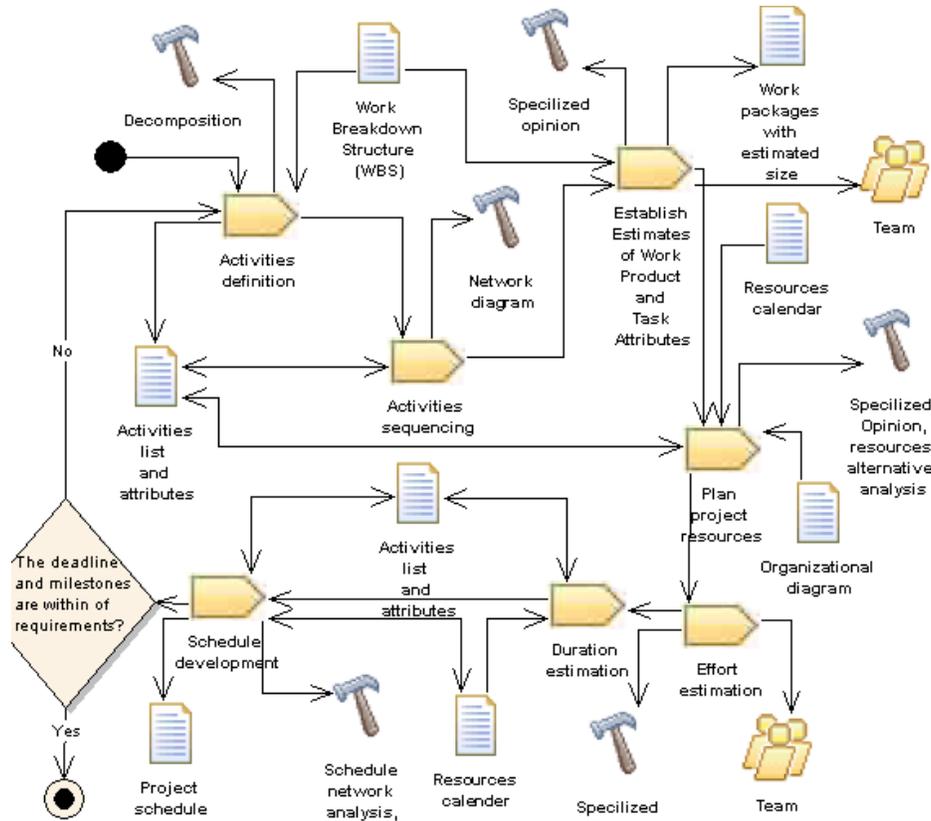


Figure 11 - Generic model for time planning aligned with CMMI-DEV and PMBOK for SME