INTERNATIONAL DESIGN CONFERENCE - DESIGN 2010
Dubrovnik - Croatia, May 17 - 20, 2010.

PRODUCT DEVELOPMENT MANAGEMENT MATURITY ASSESSEMENT: PROPOSAL OF A NEW METHOD

I. C. Paula, F. S. Fogliatto, M. E. S. Echeveste and C. A. Cristofari

Keywords: PDP management, maturity model, problem analysis

1. Introduction

Product Development Process (PDP) along with marketing and production processes is central in manufacturing companies. Several researchers have investigated the main factors impacting the performance of these processes; examples include Cooper and Kleinschmidt (1986), Page (1993), Griffin (1997), Oakley (1997), Dooley et al. (2001), Kahn (2001), Cooper et al. (2004a), Cooper et al. (2004b), Cooper et al. (2004c), Adams-Bigelow (2005), and Barckzak et al. (2006). Investigations indicated that companies which were successful in product development had common practices that were compiled and named as PDP Best Practices (BPs).

The PDP Best Practices have being incorporated in companies management routine; for instance the formalization and documentation of the PDP phase structure is a well known best practice. Salviano (2006) states that the PDP Management formalization in a company is a change process that has to be planned and implemented in stages. Nevertheless, the single effort of organizing the PDP, training the development team, creating manuals, models or graphical representations of the process does not guarantee success in the PDP; other aspects from business strategies to resources that support PDP have influence as well.

Many approaches to measure PDP Management performance have been proposed in the literature; e.g., Crosby (1984), Caffyn (1998), Rentes (2000), CMMI (2002), Rozenfeld et al. (2005), Gusberti (2006), Kahn et al. (2006) and Moultrie et al. (2006). Agostinetto and Amaral (2005) listed Change Management, Learning Organization and Maturity Models as approaches from the 90`s, which were influenced by the Total Quality Management philosophy and designed to promote continuous improvement (CI) of processes.

Maturity models were created to ease the analysis of these processes' quality and the proposition of improvements on them. Generally, a company's maturity is a function of the type and number of Best Practices routinely performed by the company, as prescribed in the Capability Maturity Model Integration (CMMI) reference model. In addition, the definition of maturity implies that a process is well understood, supported by documentation and training, is consistently applied in projects throughout the organization and is continually being monitored and improved by its users [Fraser et al. 2002, Dooley et al. 2001, Paulk et al.1993].

In practice, even after reaching a certain maturity level by performing specific BPs, problems may still remain in a company's PDP. Some problems may be related to unevenness in results obtained by routinely applying BPs in the PDP. Therefore, diagnosing a company's maturity level based on BP adoption may lead to unreliable conclusions. In this paper we propose a novel method for measuring the maturity level of a company's PDP. We start by determining how frequently PDP problems happen in the company; for that we apply a standardized questionnaire to company experts. We then input questionnaire information in a matrix (similar to QFD's house of quality, and denoted 'maturity matrix') that correlates problems and PDP Best Practices. Performing basic matrix calculations we generate an index that indicates to what extent BPs listed in the matrix are adopted in practice in the company. Associating BPs to PDP areas, we then calculate a maturity index for each of them, which are finally combined in an overall PDP maturity index.

There are two important contributions in this paper, in addition to the method itself. First, we propose a questionnaire to measure how frequently PDP problems occur in a company. The questionnaire, originally proposed by Echeveste (2003), was extended to contemplate all PDP areas and validated through interviews with PDP experts from several companies in different sectors. Second, we propose a PDP maturity matrix with entries that indicate to what extent a BP can help solving one or more of the PDP problems listed in the questionnaire. Such matrix was created using expert opinion gathered through extensive focus groups sessions and is rather generic in nature, being applicable to different industrial and service sectors.

The rest of the paper is organized as follows. In section 2 we present the recent literature related to PDP management and maturity models. In section 3 we present the proposed method for PDP maturity analysis. The conclusions and future research directions are presented in section 4.

2. Background

Since the 1990's product development has been analyzed under a broader standpoint. The idea of product development centered in technical activities evolved into a concept where businesses are supported by product development. Such new concept led to the definition of Product Development Process (PDP) by authors such as Clark and Fugimoto (1991), Cooper (1994), Cooper et al. (1999), Patterson and Fenoglio (1999), Corso and Pavesi (2000) and Crawford and Benedetto (2000).

The main reason for this evolution was the increasing importance of product and service innovation in companies' competitive performance. To strive in the market, companies had to increase the pace at which products were developed, launching them before their competitors. To enable that methods and tools to support new product development approaches have been proposed in the past 25 years, as reported by Cooper (1994). Among relevant product development approaches those considered under the expression Integrated Product Development are noteworthy; examples include Concurrent Engineering (CE) [Prasad 1997, Hartley 1998], Stage Gates methodology [Cooper 1994, O'Connor 1994, Cooper et al. 1999], Product Based Business (PBB) [Crawford and Benedetto 2000, Koufteros 2002], and more recently the Lean, Design for Six Sigma and Maturity Models.

PDP Management (PDPM) is a complex task. Being a process, activities and sub-processes in the PDPM must be chronologically organized in a network [Mundim et al. 2002]. Market information and definitions from strategic planning provide the starting guidelines to the PDPM. Market information on consumer needs is eventually materialized into products and services [Thevenot et al. 2006].

PDPM quality is a function of its standardization degree, which is enabled by the use of reference models (e.g. [Pahl and Beitz 1996, Crawford and Benedetto 2000]) and Best Practices guidelines (e.g. [PDMABoK 2003, PMBoK 2004]). Both reference models and the specialized literature summarize the Best Practices that led companies to achieve success in their PDP and which proved to be useful for the improvement of PDPM. It may be therefore inferred that the application of such Best Practices may help companies to evolve their PDPM.

PDP is generally described in three macro phases Pre-Development, Development and Post-Development. Each phase has its own objective and goals, in a cyclic and continuous effort to improve the development process [PDMABoK 2003]. Process systematization and the use of stage gates is an important BP, frequently prescribed in the aforementioned Integrated Product Development approaches. Other strategic sub-processes key in the effective coordination of PDPM activities are: strategic planning, portfolio management, marketing research, and product development strategies, in addition to PDPM support elements such as people, organization structure and culture, and process performance indexes and metrics.

The effective coordination of macro phases, sub-processes and activities provides the adequate resource and/or information to a given task in the product development project. Maturity models are tools designed to measure the existence and effectiveness of Best Practices related to each of these management macro phases, sub-processes and activities, also named as process management areas or knowledge areas.

Maturity models are PDPM enhancement tools that describe the PDP in terms of complexity (or sophistication) levels. The 'maturity' designation is due to Crosby (1984), who originally proposed a tool to evaluate the sophistication of quality management in companies. Crosby's (1984) proposal was extended to encompass other business management areas, such as the PDP, and renamed as Maturity Model.

Dooley et al. (2001) and CMMI (2002) define maturity as the degree at which a process or activity is established and practiced throughout an organization. Consequently, the maturity level is an index for the sophistication degree at which practices, techniques and standard procedures are performed in a specific area.

Fraser et al. (2002) analyzed the structure of different maturity models proposed in the last decades, proposing the following classification: (1) approaches based on the process maturity grids [Crosby 1979, Szakonyl 1994, Crosby 1996, Chiesa et al. 1996, McGrath 1996, Fraser e Moultrie 2001, MacGrath 2002, Frase and Gregory 2002, Design Council 2002], (2) process capability-based approaches [Paulk et al. 1993, Dove 1996, Earthy 1998, Shrum 2000, Wognum and Faber 2000] and (3) hybrids and likert-like questionnaire approaches [McBeth and Ferguson 1994, Caffyn 1997, Doodley et al. 2001].

Maturity grid approaches provide a qualitative description for each process area. Grid cells contain text descriptions of typical performance at different levels of maturity. In general a grid is used for each process management or knowledge area. Best Practices related to a given process knowledge area are described within each maturity level, from basic to advanced. Figure 1 presents a schematic view of a maturity grid.

Maturity Grid Approach							
		Maturity Level					
		L 1	L 2	L 3	L 4	…	L *n*
Process / Knowledge Areas	A 1	Text descriptions of typical performance at different levels of maturity					
	A 2						
	A 3						
	A 4						
	…						
	A *m*						

Figure 1. Maturity grid approaches – schematic view

Process capability approaches present a more complex structure. Analogous to maturity grids, capability approaches divide the product development process into knowledge areas; however capability models define goals and practices to be accomplished in each level, for every knowledge area, instead of a mere description of what is expected at a given level. Figure 2 presents the general structure of a capability model.

Process Capability Maturity Approach						
Maturity Level 1		Maturity Level 2		…	Maturity Level n	
Process Area 1.1		Process Area 2.1			Process Area n.1	
Objectives	Practices	Objectives	Practices		Objectives	Practices
Process Area 1.2		Process Area 2.2			Process Area n.2	
Objectives	Practices	Objectives	Practices		Objectives	Practices
Process Area 1.m		Process Area 2.m			Process Area n.m	
Objectives	Practices	Objectives	Practices		Objectives	Practices

Figure 2. Capability maturity-based approaches – schematic view

Hybrid models combine a questionnaire approach with an overall description of maturity levels, typically with no additional description for each activity. The likert-like questionnaire approaches are implemented applying a questionnaire of BPs in which respondents are asked to evaluate the relative organization's performance in relation to the BPs in use, mostly using a scale from 1 to *n* [Fraser et al. 2002]. Depending on the overall BP performance score achieved the organization is classified in a maturity level.
Figure 3, due to Fraser et al. (2002), provides a summary of characteristics for the maturity approaches described above. Approaches are generally used to measure the extent of use of best practices and to guide PDPM improvement in organizations. Many BPs have been investigated in the literature, and are generally assumed to impact in a company's PDPM success.

	Maturity Grids approach	Capability Process Approach	Mixed Maturity Approach
Approach Structure	Usually split the process in knowledge areas decribing them, qualitatively, in sophistication levels	Usually split the process in knowledge areas and fix a set of objectives and practices for each maturity level	Usually split the process into knowledge areas, but also split the knowledge areas in BP level, that permits the analyst to access, from a simple scale, how well the company does a given BP
Detailing improvement degree achieved with approaches	Poor detailing degree. The maturity evaluation is made by knowledge area textual description, for a given maturity level. Therefore, this approach indicates the knowledge area prioritized for improvement efforts, but not the BP that should be implemented to achieve a process evolvement	Better detailing degree. The maturity access is made by the fixed objective and practices for each knowledge area evaluation. As a result, this approach indicates the possible BP that should be implemented to achieve a process improvement for each knowledge area	Larger detailing degree. The maturity evaluation is made by the knowledge areas or BP quantitative evaluation. As a result, this approach indicates the priority knowledge areas to receive the improvement efforts and also the BP which should be implemented to process improvement
How the approaches are implemented	This approach is implemented by a questionnaire, workshops and auditing to make a qualitative evaluation of maturity levels	This approach is implemented by structured questionnaire, interview, checklists and documents analyses to make a qualitative and quantitative investigation of objectives performance, related with every single BP	This approach is implemented by structured questionnaire and interviews with a team invited to punctuate, using a simple scale to measure how well the company does a given BP
Approaches Strengths	Straightforward application, the scope of improvement and detailing are built by the process staff and short run application	Process sophistication larger detailing degree, the evaluation is less subjective than the other approaches because it is performed by a foreign expert person	Straightforward application, easy visualization and understanding of process practices use degree
Approaches Weaknesses	Poor detailing degree and can be affected by the respondents tends and preferences	Complex aplication, it demands an expert professional and a long period of application	Intermediate detailing degree; high subjective evaluation degree, the questionnaire may be long and hard if a deep evaluation is performed

Figure 3. Maturity approaches analysis and comparison

Although designed as quality assessment tools, maturity models may also be used to set benchmarks when choosing suppliers, as proposed by Salviano (2006). Amaral and Rozenfeld (2007) state that maturity models are efficient in clarifying improvement opportunities in a specific process, and for that reason they provide the basis for planning the scope and setting the starting point of process improvement projects.
Maturity scores derived from the approaches above indicate the BPs' degree of usage. Since BPs are adopted by companies to tackle problems or support activities in the PDPM, it would be more appropriate to measure their efficiency on reducing such problems. In addition, a given PDPM

problem may not be directly related to a single BP, but require the joint use of several Best Practices to be minimized or even eliminated. The method we propose attempts at solving such drawbacks, providing a maturity score that reflects the complexity of the relationships between BPs and their problems they aim at.
Furthermore, maturity model approaches available in the literature indicate process improvement areas or BPs that may be converted in tactical/operational improvement projects, but not always define their implementation priority leaving that task to managers. In section 3, we present a proposition to prioritize improvement projects based on the PDP area maturity level.

3. Proposed method

Echeveste (2003) created a questionnaire to be used as diagnostic tool in which typical PDPM problems are listed. Respondents are asked to evaluate the frequency in which problems take place in their organizations. Echeveste (2003) concluded that problems are easily remembered and commented by leaders and product development teams. In contrast, BPs are not so easily recognized by respondents mostly because BPs knowledge or diffusion depend on the organization's maturity level, culture, common language and training. The proposed questionnaire is an important tool designed to analyze problems in search of their root causes, which may be helpful in maturity analysis.
In our method the relationship between PDPM typical problems and Management Best Practices is made explicit through a 'maturity matrix'. PDPM problems are evaluated regarding their incidence by company experts and the information is inputted in the matrix. As a result, a prioritized list of BPs that minimize problems identified by the respondents is produced. The list of BPs enables the identification of improvement project opportunities, which are finally prioritized in a portfolio. Our method is implemented in two stages (*i*) data collection and maturity analysis, and (*ii*) identification of PDPM improvement project opportunities, organized in a prioritized portfolio. The two stages are divided in six phases, summarized in Figure 4.

Macro-Stages	Phases	Tools
Problem Data Collection and Maturity Analysis	3.1 PDPM problems incidence frequency identification	Typical problems questionnaire
	3.2 Maturity level and development scores analysis	M matrix
	3.3 PDPM improvement opportunities portfolio consolidation	Analysis tools (e.g. Box Plot)
PDP Improvement Project Opportunities	3.4 Priorization criteria and attributes determination	Decision making tools (e.g. MAUT)
	3.5 Improvement opportunities priorization	Project Management practices
	3.6 Improvement opportunities portfolio ranking and definition	Graphic tools (e.g. Pareto graphics)

Figure 4. Macro stages, phases and tools from proposed PDPM Maturity Analysis Method

Phases 3.3, 3.4 and 3.6 in Figure 4 may be implemented using traditional quality tools; on the other hand, phases 3.1, 3.2 and 3.5 are performed using matrices developed for the Maturity Analysis method we propose.

3.1 Data gathering on PDPM typical problems

A questionnaire was adapted from Echeveste (2003) and Gusberti (2006), and denoted by 'Typical problems questionnaire'. The tool was developed to collect data on PDPM problems from company experts. More specifically, we are interested in identifying how frequently each problem listed in the questionnaire occurs in the company.
The original questionnaire presented 81 problems distributed in 12 groups. In our method some problems were collapsed and a new questionnaire comprised of 52 independent problems, shown in Appendix A , was created. The questionnaire may be visualized in:

[http://spreadsheets.google.com/pub?key=tC1NvHKg67uSo0MAWpeFqiA&single=true&gid=24&output=html]. To measure how frequently problems take place in the company's product development routine, a 9 point scale with five descriptive anchors is presented to the analyst; see Figure 5. The variable f_j gives the frequency in which the j-th problem, j = 1, ..., 52, occurs in the company. Ideally the questionnaire is applied to a multidisciplinary team knowledgeable of the different PDPM areas, such that responses reflect group consensus.

<table>
<tr><th colspan="2">Problems Incidence Frequency Scale</th></tr>
<tr><td>1</td><td>Never Occur (0-10 % of the projects)</td></tr>
<tr><td>2</td><td rowspan="2">Rarely Occur (10 - 20 % of the projects)</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td><td rowspan="2">Seldom Occur (20 - 50 % of the projects)</td></tr>
<tr><td>5</td></tr>
<tr><td>6</td><td rowspan="2">Frequently Occur (50 - 90 % of the projects)</td></tr>
<tr><td>7</td></tr>
<tr><td>8</td><td rowspan="2">Always Occur (90 - 100 % of the projects)</td></tr>
<tr><td>9</td></tr>
</table>

Figure 5. Scale to be used in the Typical Problems Questionnaire

3.2 Maturity assessment

f_j values are inputted in the maturity matrix **M**. The matrix is comprised of a number of elements, being the matrix of relations **R** the most important. A general view of matrix **M** is given in Figure 6, with elements described in subsections to follow.

<table>
<tr><th colspan="5" rowspan="3">Maturity Level Matrix (M)</th><th colspan="4">Problems Questionnaire frequencies</th><th rowspan="3">Inferior level</th><th rowspan="3">Criticality score</th><th rowspan="3">Superior level</th><th rowspan="3">Development score</th></tr>
<tr><td>P1</td><td>P2</td><td>(....)</td><td>P52</td></tr>
<tr><td>$f1$</td><td>$f2$</td><td>(....)</td><td>$f52$</td></tr>
<tr><td rowspan="5">BPR</td><td rowspan="4">3 PDPM areas</td><td rowspan="4">10 knowledge areas</td><td rowspan="4">30 habilities</td><td>BP 1</td><td colspan="4" rowspan="4">R Matrix (rij)</td><td>il_1</td><td>cr_1</td><td>sl_1</td><td>DS_1</td></tr>
<tr><td>BP 2</td><td>il_2</td><td>cr_2</td><td>sl_2</td><td>Ds_2</td></tr>
<tr><td>Best Practices (...)</td><td>.
.
.</td><td>.
.
.</td><td>.
.
.</td><td>.
.
.</td></tr>
<tr><td>BP 95</td><td>il_{95}</td><td>cr_{95}</td><td>sl_{95}</td><td>DS_{95}</td></tr>
<tr><td colspan="4">Problems impact</td><td>pi_1</td><td>pi_2</td><td>....</td><td>pi_{52}</td></tr>
</table>

Figure 6. Maturity matrix (M)

3.2.1 Best practices reference (BPR)

The Best Practices Reference (BPR) is a hierarchical structure in which PDPM Best Practices are deployed (Figure 6). The BPR was generated from a Content Analysis (Bardin, 1994) on (*i*) PDMA (Product Development and Management Institute) and APQC (American Productive and Quality Control) reported studies on BPs performed in companies; (ii) BPs guidelines such as PDMABoK (2003) and PMBoK (2004); and (*iii*) PDPM reference models.

The BPR describes the PDP management in 5 levels, as depicted in Figure 8. They comprise three process management areas (g = 3) deployed into 10 knowledge areas (k = 10), which are detailed in Appendix B. The knowledge areas are deployed in 95 Best Practices (i = 95) and 302 sub-process descriptions. The BPR provides a broad reference that includes strategic, tactical operational and support BPs.

3.2.2 Matrix of relations

The matrix of relations (**R**) is the main element of the maturity matrix, and one of the most significant contributions in the proposed method. Entries r_{ij} in **R** give an expert opinion-based assessment on how the *i*-th BP may help tackling the *j*-th problem. Values of r_{ij} range from 0 (the *i*-th BP has no relation with the *j*-th problem) to 9 (the *i*-th BP definitely minimizes or eliminates the occurrence of the *j*-th problem). 52 problems and 95 BPs (from the 4th deployment level of the BPR in Figure 7) were considered and a total of 4940 relations were analyzed.

Relations r_{ij} were analyzed in focus groups with experts in PDPM. Seven expert groups were consulted about the following knowledge areas (Figure 8): (1) corporate strategy, (2) product/project development strategy; (3) marketing research and customers; (4) portfolio management /culture and innovation supportive environment; (5) process systematization; (6) gates, metrics and performance evaluation; and (7) people and organization for product development. Experts consulted have participated in more than one group.

An interview protocol was created for each focus group. The first part of the protocol was comprised of a general description of the research project, including knowledge areas and the focus group objectives. In the second part, BPs and the knowledge area under analysis were presented. In the third part the logic behind the relations analysis and the scale to be used were described.

Experts were asked to answer the following question: 'how the *i*-th BP collaborates to minimize or eliminate the occurrence of the *j*-th problem?' The answer to the question resulted in the values of r_{ij}. Respondents evaluated relations using the 9-point scale previously described. Focus group sessions lasted for one and a half hour in average. Forty four (44) focus groups sessions were carried out, as listed in Figure 7. In total, 4940 relationships were analyzed. The resulting matrix is presented in (http://spreadsheets.google.com/pub?key=tc267PkKjq6Wb_X9HCGutcg&single=true&gid=27&output=html).

Specialists Groups		Enterview numbers
Group 1	Corporate Strategy	7
Group 2	Product Development Strategy	7
Group 3	Market Research and customers	6
Group 4	Portfolio Management and Culture and climate to innovation	7
Group 5	Process systematization	5
Group 6	Gates, Metrics and performance evaluation	6
Group 7	People and Organization for product development	6

Figure 7. Number of focus group for each knowledge area

In view of the effort to analyze the relations in matrix **R** we do not recommend changes in its weights. Matrix **R** is the basic tool to assess a company's PDPM maturity level. For that, basic matrix calculations must be performed using the variables and indices described in the next section.

3.2.3 Variables and indices

- f_j – describes the frequency in which the *j*-th problem occurs in the company, and is obtained from company managers and technicians using the Typical Problems Questionnaire described in section 3.1.
- r_{ij} – gives the relation between BP *i* and problem *j*, obtained as described in section 3.2.2.
- p_{ij} – gives the importance of problem *j* determined as a function of its relations with all BPs; i.e.:

$$pi_j = \sum_{i=1}^{95} r_{ij} \quad , j = 1, \dots, 52 \tag{1}$$

- sl_i – gives the worst possible score for not implementing properly the *i*-th best practice *i* as a function of three terms (note that $f_j = 9$ denotes the largest frequency score assignable to a problem):

$$sl_i = \sum_{j=1}^{52} r_{ij} \times pi_j \times 9,\ i = 1,\dots,95 \quad (2)$$

- il_i – gives the best possible score for implementing properly the *i*-th best practice *i*, where $f_j = 1$ denotes a very low frequency score assigned to a problem:

$$il_i = \sum_{j=1}^{52} r_{ij} \times pi_j \times 1,\ i = 1,\dots,95 \quad (3)$$

- cr_i – gives the criticality score for the *i*-th BP, calculated as follows:

$$cr_i = \sum_{j=1}^{52} r_{ij} \times pi_j \times f_j,\ i = 1,\dots,95 \quad (4)$$

- DS_i – gives the development score for Best Practice *i* in a 0 to 10 scale, in which 10 indicates the best development score:

$$DS_i = \frac{cr_i - il_i}{sl_i - il_i} \times 10,\ i = 1,\dots,95 \quad (5)$$

- DS_k – gives the development score for Knowledge Area *k*, calculated as the geometric average of DS_i scores in that Area:

$$DS_k = \left(\prod_{i \in k} DS_i\right)^{1/\sum i},\ k = 1,\dots,10 \quad (6)$$

- ML_k – gives the maturity score Knowledge Area *k* as a function of its DS_k score, using the mapping in Figure 8.

Knowledge Area K Maturity Level Score (ML_k)	DS_k intervals
Maturity Level 1	0 - 2,50
Maturity Level 2	2,51 - 5,00
Maturity Level 3	5,01 - 7,25
Maturity Level 4	7,26 - 9,50
Maturity Level 5	9,51 - 10,00

Figure 8. Maturity levels as a function of

- ML_g – Maturity Score for Management Area *g*, which is bounded by the lowest ML_k score within area *g* (where *g* = *S* (Strategic), *TO* (Tactical-Operational), *SU* (Support)); i.e.:

$$ML_g = \min_{k \in g}(ML_k) \quad (7)$$

- GML – gives the PDPM's overall maturity level, which is bounded by the lowest ML_g score, as follows:

$$GML = \min_{\text{all } g} ML_g \quad (8)$$

3.3 Portfolio of PDPM improvement opportunities

This is the last phase in the method's first stage, in which knowledge areas or process management areas are analyzed. Management of PDP requires balance among process management areas

(Strategic, Tactical-Operational and Support). To accomplish that our method prescribes the analysis of typical problems, focusing on the minimization of those in knowledge areas with low development scores, which are denoted critical areas. Graphing DS_k values within area g using a Boxplot may help identifying atypical behaviors and trends in the values, providing further insight into the area's deficiencies. Best Practices associated with critical knowledge areas are deemed as improvement opportunities, since developing such practices may reduce the frequency of problems associated with those areas. Therefore critical areas are analyzed with the objective of creating a portfolio of improvement opportunities compatible with the organization's profile. The development of such profile is contemplated in the second stage of our method.

3.4 Setting up a company's profile

This is the first phase in stage II of our method. The group of managers responsible for the maturity analysis is asked to establish the company's profile, to guide the improvement opportunities' decision making process. Such profile consists of criteria and characteristics chosen and weighted in importance by managers, which will be used to compare improvement opportunities.

We propose using a Multi-attribute Utility (MAUT) analysis to investigate trade-offs and set weights for the improvement opportunities. MAUT organizes complex problems in a hierarchical structure in which a large number of qualitative and quantitative factors are subjectively evaluated (Min, 1994). Figure 9 displays our proposition of criteria and characteristics to be considered in the analysis. The first criterion evaluates the improvement opportunity regarding is importance, i.e. how significant it is to implement that BP; the second criterion evaluates the improvement opportunity regarding its feasibility, i.e. the effort required in its implementation.

Objective	Criteria	Characteristics	Importance	Weight (cw_n)
Improvement opportunities Prioritization	Improvement Opportunity Importance	Strategic Objective Achievement		
		Weakness of PDP Elimination		
		Organizational Change		
		First Criteria total		
	Improvement Opportunity Feasibility	Technical Risk		
		HR Qualify Need		
		Investment Need		
		Second Criteria total		

Figure 9. MAUT - Multiattribute utility structure

To evaluate each characteristic's importance weight cw_n, a 0 to 100% scale is used. The set of weights describes the analysts' decision making profile.

3.5 Prioritizing improvement opportunities

Improvement opportunities in each critical area, listed in section 3.4, are analyzed in this phase. For that a Prioritization Matrix (P), exemplified in Figure 11, is used. Improvement opportunities are listed in the rows of P along with their respective criticality scores (cr_i); P's columns are comprised of the criteria analyzed in section 3.4, and their importance weights. Experts are asked to determine how improvement opportunity i satisfies evaluation criterion n yielding matrix entries p_{in} $(i = 1, \dots, I;\ n = 1, \dots, N)$. A 0 to 9 scale is used for that, in which 9 means strong relationship, and 0 means no relationship between improvement opportunity i and criterion n. The final score for the i-th improvement opportunity (Tp_i) is calculated as follows:

$$Tp_i = \sum_{n=1}^{N} (p_{in} \times cw_j) \times cr_i \,,\ i = 1, \dots, I \qquad (9)$$

<table>
<tr><th colspan="9">Prioritization Matrix (P)</th></tr>
<tr><th rowspan="3">BPR</th><th colspan="3">Improvement Opportunity Importance</th><th colspan="3">Improvement Opportunity Feasibility</th><th rowspan="3">Criticality score</th><th rowspan="3">Improvement opportunity Weigh</th></tr>
<tr><th>Strategic Objective Achievement</th><th>Weakness of PDP Elimination</th><th>Organizational Change</th><th>Technical Risk</th><th>HR Qualify Need</th><th>Investment Need</th></tr>
<tr><th>cw_1</th><th>cw_2</th><th>cw_3</th><th>cw_4</th><th>cw_5</th><th>cw_6</th></tr>
<tr><td>BP_1</td><td colspan="6" rowspan="5">p_{in}</td><td>cr_1</td><td>Tp_1</td></tr>
<tr><td>BP_2</td><td>cr_2</td><td>Tp_2</td></tr>
<tr><td>⋮</td><td>⋮</td><td>⋮</td></tr>
<tr><td>⋮</td><td>⋮</td><td>⋮</td></tr>
<tr><td>BP_{95}</td><td>cr_{95}</td><td>$Tp\ 95$</td></tr>
</table>

Figure 10. Prioritization Matrix P

3.6 Setting up a portfolio of improvement opportunities

This is the last phase in the second stage. Experts will organize the Tp_i scores and define the improvement opportunities portfolio. To visualize the ranking of improvement opportunities, graphical tools such as the Pareto chart, may be used. The number of opportunities to be included in the portfolio depends on the availability of financial and human resources in the company. It is important to note that a portfolio comprised of the highest scored improvement opportunities will be compatible with the companies profile, since that was one of the aspects considered in the scoring process.

4. Conclusion

In this paper we present a new method for PDPM maturity assessment. The method aims at helping managers to identify and prioritize improvement opportunities related to best practices in the PDPM. The proposed method is organized in two stages and six phases. In the first stage, information is collected using a problems questionnaire. The PDPM problems frequency are necessary for the process maturity and knowledge areas assessement. The second stage focus on organizing a portfolio of improvement opportunities.

The method presents at least two important contributions. The first is a questionnaire proposed to measure the frequency in which PDP problems occur in a company. The second is a maturity matrix with entries that indicate to what extent a Best Practice can help solving one or more of the PDP problems listed in the questionnaire. Both contributions were created based on extensive literature research, and organized gathering of expert opinion. The method has been applied successfully in Brazilian companies.

Future research may be conveyed in three directions. First the relation of our method with change management methods available in the literature, such as those reported by Caffyn (1998), Rentes (2000) and Gusberti (2006) needs to be clarified, since those methods focus on the PDP improvement cycle. The maturity assessment we propose may be useful in the diagnosis phase in the above mentioned change management methods. Second, detailing the 95 Best Practices listed in our model in terms of tools and methods needed for their implementation may result in a repository of tools useful in the PDPM. Third, future research should focus on the elaboration of textual descriptions for each maturity level in this proposed method, similar to the descriptions present in maturity grids and capacity models.

References

Adans-Bigelow, M., "First results From the 2003 Comparative Performance Assessment Study", 2005, In Kahn, B. K., "The PDMA Hand Book of New Product Development", John Wiley and Sons, 2005.

Amaral, D. C., Rozenfeld, H,. "Integrating new product development process references with maturity and changes management", ICED 07, Paris, 2007.

Barczak, G., Kahn, K., Moss, R., "An Exploratory Investigation of NPD Practices in Non-profit Organization", The Journal of Product Innovation and Management, Vol. 23, 2006, pp 512-527.

Baxter, M., "Projeto de produto: um guia prático para o design de novos produtos", Editora Edgard Blücher Ltda, 1998.

Caffyn, S. J., "The scope for the application of continuous improvement to the process to the new product development", University of Bringhto, UK, 1998.

Cooper, R. G., Kleinschmidt, E. J., "An investigating into a New Product Process: Steps, Deficiencies and Impact", The Journal of Product Innovation and Management, Vol.3, 1986, pp 71-85.

Cooper, R. G., Edgett, S. J., Kleinschmidt, E. J., "Benchmarking best NPD practices I", Research – Technology Management, Vol. 47, No. 1, 2004 a, pp 31 – 43.

Cooper, R. G., Edgett, S. J., Kleinschmidt, E. J., "Benchmarking best NPD practices II", Research – Technology Management, Vol. 47, No. 3, 2004 b, pp 50 – 59.

Cooper, R. G., Edgett, S. J., Kleinschmidt, E. J., "Benchmarking best NPD practices III", Research – Technology Management Vol. 47, No. 6,2004 c, pp 43 – 55.

Cooper, R. G., "New Product Success in Industrial Firms", Industrial Marketing Management, Vol. 11, No. 2,1982, pp 215-223.

Costa, J. M. H., Rozenfeld, H., "Proposal of the BPM Method for Improving NPD Process", Product Management & Development, Vol. 5, No. 1, 2007, pp 25-32.

CMMI, "Capability Maturity Model Integration, version 1.1", Carnegie Mellon Institute, 2002.

Crosby, B. P., "Qualidade é investimento: a arte de garantir a qualidade", José Olympo, Rio de Janeiro, 1984.

Dooley, K., Subra, A., Anderson, J., "Maturity and its impact on the new product development project performance", Research in Engineering Design, Vol. 13, 2001, pp 23-29.

Echeveste, M. E. S., "Uma abordagem apara e estruturação e controle do processo de desenvolvimento de produtos", PPGEP/UFRGS, 2003.

Fraser, P., Moultrie, J., Gregory, M., "The use of maturity models / grids as a tool in assessing product development capability", IEEE, 2002.

Griffin, A., "PDMA Research on the New Product Development Practices: Update Trends and Benchmarking Best Practices", The Journal of Product Innovation and Management, Vol. 14 1997, pp 429-458.

Gusberti, T. D. H, "Modelo de intervenção para o processo de desenvolvimento de produto farmacêutico para pequenas e médias empresas", PPGEP/UFRGS, 2006.

Kahn K., "An Exploratory Investigation of New Product Development Forecasting Practices", The Journal of Product Innovation and Management, Vol. 19, 2001, pp 133-143.

Kahn, K., Barzack, G., Moss, R., "Establishing a NPD Best practice Framework", The Journal of Product Innovation and Management, Vol. 23, 2006, pp 106-116.

Moultrie, J., Clarckson, P. J., Probert, D., "A Tool to Evaluate Design Performance in SMEs", International Journal of Productivity and Performance Management, Vol. 55, No. 3/4, 2006, pp 184-216.

Mundim, A. P. F., Rozenfeld, H., Amaral, D. C., Silva, S. L., Guerreiro, V,, Horta, L. C., "Aplicando o cenário de desenvolvimento de produtos em um caso prático de capacitação Profissional", Gestão & Produção, Vol. 9, No. 1, 2002.

Oakley, P., "Hight-Tech NPD Success through Fasters Overseas Launch", Journal of Product & Brand Management, Vol. 6, No. 4, 1997, pp 260-274.

Page, A., "Assessing New Product Development Practices and Performance: Establishing Crucial Norms", The Journal of Product Innovation and Management, Vol. 10, 1993, pp 273-290.

Pahl, G., Beitz, W., Feldhusen, J, Grote, K., "Projeto na engenharia: fundamentos do desenvolvimento de produtos, métodos e aplicações", Edgar Blücher Ltda, São Paulo, 2005.

Paula, I. C., Ribeiro, J.L.D., "A Proposal of a Reference Model for the Pharmaceutical PDP Management", Brazilian Journal of Operations & Production Management, Vol.4, No 2, 2007, pp 05-32.

PDMABoK, "The Body of Knowledge of PDMA", 2003, In http://www.pdmabok.org/ , acessed im April, 11, 2007.

PMBoK, "Um guia do conjunto de conhecimentos em gerenciamento de projetos", Project Management Institute (PMI), 2004.

Patterson, M.L., Fenoglio, J.A., "Leading Product Innovation. Accelerating Growht in the Product Based Business", John Wiley & Sons, Inc. New York, 1999.
Romano, L. N.. "Modelo de referência para o processo de desenvolvimento de máquinas agrícolas", PPGEM/UFSC, Santa Catarina, 2003.
Rozenfeld, H., Scalice , R., Amaral, D. C., "Proposta de um modelo de maturidade para o processo de desenvolvimento de produtos.", Proceedings of V CBGDP, Curitiba, 2005.
Rozenfeld, H., Forcellini, F. A., Amaral, D. C., Toledo, J. C., Silva, S. L., Alliprandini, D. H., Scalice, R. K., "Gestão de desenvolvimento de produtos: Uma referencia para a melhoria do processo", Saraiva, 2006.
Salviano, C. F., "Uma proposta orientada a perfis de capacidade de processo para evolução de melhoria de processo de software", FEEC/UNICAMP, 2006.
Thevenot, H. J., Steva, E. D., Okudan, G. E., Simpson, T. W., "A Multiattribute Utility Theory: Based Approach to Product Line Consolidation and Selection", Proceedings of the International Design Engineering and Technical Conference & Computer and information Engineering Conference – ASME 2006, Philadelphia, 2006.

Dr. Istefani Carísio de Paula
Professor
Rio Grande do Sul Federal University
Porto Alegre, Rio Grande do Sul, Brazil
Telephone: (55) 51 3308-4298
Telefax: (55) 51 3308-4007
Email: istefani@producao.ufrgs.br
URL: http://www.producao.ufrgs.br