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Establishing a Conceptual Model for Assessing Project Management Maturity in Industrial Companies

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The number of projects undertaken by companies nowadays is significant. Therefore, there is a need to establish processes in the company supporting and increasing project management efficacy. In order to achieve this, the companies need to know how good they are at organizational project management, taking into consideration different perspectives. Knowing their strengths and weaknesses, they are able to improve their activities in challenging areas. In view of the critical literature review and interviews with chosen companies, the article proposes a conceptual model for assessing project management maturity in industrial companies. The model is based on four assessment areas. Three of them (human resources, methods & tools, and environment) represent the traditional approach to maturity measurement, whilst the fourth, knowledge management, represents a new approach to the topic. The model was tested in over 100 companies in the machinery industry to verify its practical application and establish valid results of implementation, which have not been previously explored.

Keywords: project management, model, assessment, maturity, industry, knowledge management.

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1. INTRODUCTION

The need for models that could be implemented in industry is recognized by authors of publications in different areas of expertise (Bernardo, Angel, & Eloisa, 2011; Jasemi, Kimiagari, & Memariani, 2011; Kamrani, Adat, & Azimi, 2011; Metikurke & Shekar, 2011). The importance of new product development from a different perspective was recognized, for example, by Adams-Bigelow et al. (2006) and measured by Metikurke & Shekar (2011) and Kahn, Barczak, & Moss (2006). New product development is a laborious endeavour that must be managed properly. Therefore, industrial companies are interested in having an efficient tool to measure how good they are when it comes to project management. That assessment must be done in different areas, including the set of best practices as the reference.

Moreover, Kwak (2000) noticed that there is an influence on the company's project management maturity level and the key performance indicators of projects. Furthermore, Spalek (2014a, 2014b), based on his studies in the industrial companies, shows that increasing the maturity level potentially reduces the costs and time of ongoing and new projects.

In fact, industrial companies are managing an increasing number of projects every year (Aubry et al., 2010). Besides the typical operational representatives in the project-oriented environment like the IT and construction sectors, companies in other industries have increasingly embraced newer project management methods (Cho & Moon, 2006; Grant & Pennypacker, 2006; Liu, Ma, & Li, 2004; McBride, Henderson-Sellers, & Zowghi, 2004; C. T. Wang, Wang, Chu, & Chao, 2001). A good example is the machinery sector, which is very focused on the efficient development of new products that are then used by other industries. The products of machinery industry are divided into those of general purpose, heavy-industry machines and their elements and components, totalling more than 200 products (ISIC, 2008). Therefore, companies in the machinery industry are a kind of backbone of the entire economy and are located all over the world. However, the most significant production comes from the EU (European Union), ASEAN+6 (Japan, Korea, Singapore, Indonesia, Malaysia, Philippines, Thailand, China (including Hong Kong), Brunei, Cambodia, Laos, Burma, Vietnam, India, Australia, New Zealand) and NAFTA & UNASUR (Canada, Mexico, USA, Argentina, Bolivia, Brasilia, Chile, Columbia, Ecuador, Guyana, Paraguay, Peru, Surinam, Uruguay, Venezuela) areas (Kimura & Obashi, 2010). The main customers of products of the machinery industry are companies from the following industries: construction, agriculture, mining, steelworks, food and textiles.

As companies have undertaken increasingly complex and more time-/cost-sensitive projects, it has become crucial to measure how they perform in project management and to identify the areas for further improvement (Hillson, 2003). Of special importance are the ability to conduct assessments and to identify the path for further development, which seem to be essential in today's turbulent times (Caprioara & Paraschivescu, 2009; Shi & Jia, 2009).

One of the first widely recognized methods (Watts, 1989) for evaluating project management performance was the Capability Maturity Model (CMM) proposed by the Software Engineering Institute (SEI), designed for software development purposes only (Paulk et al. 1993). Then, its successor was the Capability Maturity Model Integration (CMMI) model, which was proposed by the same organization at the beginning of the present century (Scampi, 2006, Twaites, Collofello, & Zenzen, 2004).

As the "maturity" idea started to become more widely recognized, other organizations and individuals (Becker, Knackstedt, & Poppelbuss, 2009; Buch, Edwards, & Eriksson, 2009; Crawford, 2006; Grant & Pennypacker, 2006; Ha & Lv, 2006; Khoshgoftar & Osman, 2009; McBride et al., 2004; F. L. Wang, 2005) proposed their maturity assessment models. However, they were and still are mostly focused on IT (Becker et al., 2009) and organizational processes in the company (Hillson, 2003).

With the application of project management in the multitude of industries, the need to assess their maturity seems to be crucial in accordance with the requirement of improvement of their efficacy in new product development (Metikurke & Shekar, 2011; Mortensen, Harlou, & Haug, 2008) and associated aspects of project management in manufacturing (Allenbach & Huffman, 2000; Cho, Moon, 2006, Wang & Liang, 2006).

Therefore, there is a need to propose a conceptual model that could be used for assessing project management maturity in the industrial environment.

2. DEVELOPMENT OF THE MATURITY ASSESSMENT FRAMEWORK

The research framework consists of five stages: (1) overview of existing models, (2) initial proposal of the framework, (3) testing the initial framework in the industrial environment and (4) based on the results, proposing the final conceptual model that could be widely applied in industrial practice; finally: (5) validating the model in companies in the machinery industry.

2.1. Overview of the Existing Maturity Models

In the first stage, we decided to review available maturity models with regard to their usability in an industrial environment. Moreover, our intention was to find out what they have in common and what their strengths and weaknesses are. That knowledge was the necessary basis for building the initial concept framework for maturity assessment.

According to a recent study by Wendler (2012), there are more than 200 articles related to project management maturity. However, the range of topics varies significantly (Figure 1). Only 32 of them propose the validated branch model, out of which the vast majority are in Information Technology (IT) and none for companies in the machinery industry.

We recognize that the significant majority and the most commonly used models in IT (e.g. SPICE, PRINCE, PMMM, Kerzner's Project Management Maturity Model) have their roots in the CMMI (CMM) model (Twaites et al., 2004). However, the main focus of the majority of models is process-oriented (e.g. CMMI, Hammer's PEMM, Process Maturity Model, BPMM), while some describe organizational maturity (e.g. OPM3, OGC P3M3, ProMMM), as shown in Table 1.

Table 1. A comparison of the most common maturity models.

Model name	Process-oriented	Organization-oriented
CMMI (Scampi, 2006)	X	
Hammer's PEMM (Hammer, 2007)	X	
Process Maturity Model (Gorschek et al., 2012)	X	
BPMM (Lee, Lee, & Kang, 2007)	X	
OPM3 (PMI, 2008)		X
OGC P3M3 (OGC, 2006)		X
ProMMM (Hillson, 2003)		X

A number of models comprehensively test project management in an organization against the completeness of the multi-processes or the detailed alignment with knowledge areas, which makes the assessment of maturity challenging to perform in practice. Therefore, consulting companies have specialized in providing maturity level assessment.

The most extensive and comprehensive model is OPM3, developed by the Project Management Institute (Project Management Institute, 2008). The OPM3 model gathers best practices and associated capabilities with KPIs and metrics as well. Moreover, this model is a powerful tool and is also the most universal one (Khoshgoftar & Osman, 2009). It is designed to be used by different organizations. However, its practical application can be challenging and time-consuming.

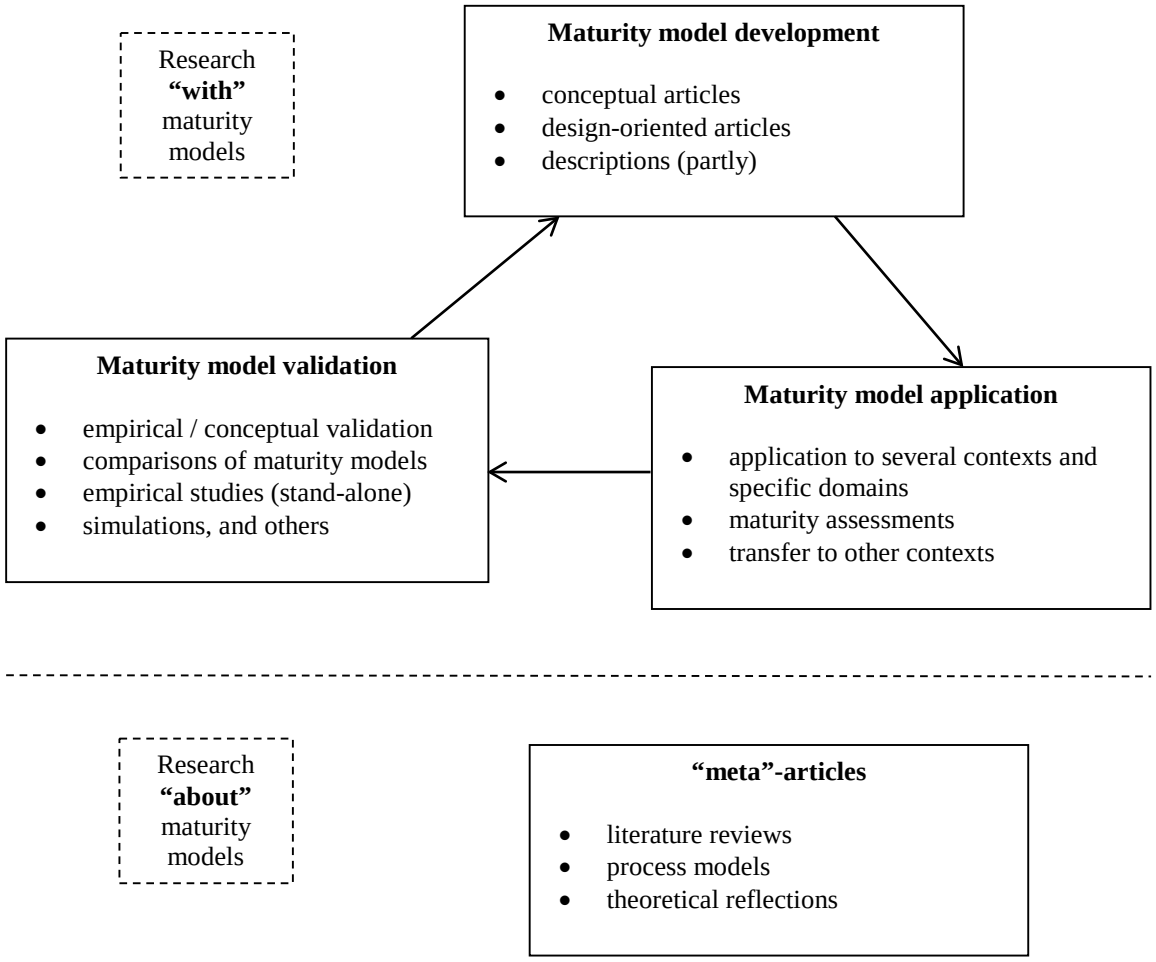

Figure 1. Topics covered by articles in maturity model research (Wendler, 2012, p. 1331)

In common, the majority of project management maturity models assess maturity using a scale with 1 to 4-5 levels (where level 1 is the lowest and levels 4 or 5 represent the highest maturity) in different testing areas of processes and knowledge in project management. Some of the models could use the percentage scale (0-100%) instead of levels to represent maturity in certain domains. A different approach is used in the OPM3 model where the outcome of the assessment is not rated. It is a multidimensional, ongoing assessment regarding the relationships between best practices, capabilities and KPIs, in order to continuously improve maturity.

Hillson (2003) criticizes the complexity of the vast majority of models and points out that they are too detailed and place too heavy a reliance on theoretical aspects. Therefore, they are hard to apply in practice. To reduce this disadvantage, he proposes some assessment simplifications (without being overly simplistic) in his ProMMM model. Therefore, he proposes a reduction in the number of areas of assessment and an increased focus on the project management context, not only on processes.

2.2. Building Initial Framework For Maturity Assessment

Following Hillson's (2003) concept, we decided to build a framework for maturity assessment in the industrial environment with a special focus on new product development. We initially believed that to assess specific maturity in the manufacturing area, it is sufficient to limit the assessment to three areas related to project management processes and organizational context, as the majority of existing models demonstrate. However, we recognized that it is crucial to add one

more, the area of knowledge management, which is one of the most important topics for companies nowadays (Y. K. Cho, Moore, & Hill, 2003; Friesl, Sackmann, & Kremser, 2011; Gasik, 2011; Lai, 2011; Shida, Yamamoto, Matsumoto, & Kanazawa, 2007; C. B. Wang, Chen, Chen, & Chu, 2005; Zhou, Son, Chen, Zhang, & Ma, 2007).

Therefore, the proposed initial framework included assessment areas on the following: PM tools and methods / processes, Organizational context / Management system, Human Resources / Skills and Knowledge, and finally, new Knowledge Management (which is not a subject of separate measurement in the other models).

2.3 Testing the Framework in the Industrial Environment

The initial framework was tested in three industrial companies. The research was conducted using the case study method (Rowley, 2002). Using the initial framework, the set of testing questions was built to facilitate the maturity assessment. The interview was conducted in several days, with staff holding different positions in the organization. During the analyses of results, it was shown that some areas should be described in another way and, therefore, the model was modified accordingly. However, the core idea remained unchanged. As a result, the final conceptual model for assessing project management maturity was proposed. Moreover, after testing the model, it occurred that the preference of industrial companies is to clearly distinguish the assessment areas and present the results on a short scale, where a scale of 1-5 was favourable and the most understandable for them. Furthermore, they preferred the simplicity of the assessment model over going into too many details. Those prerequisites were taken into consideration when building the final shape of the model.

2.4. A Conceptual Model For Assessing Project Management Maturity

Based on the literature overview and interviews with staff from the industrial companies, we propose the conceptual model with the following assumptions (Figure 2): (1) the maturity assessment should be conducted in four areas, (2) the assessment should be conducted in each area separately, (2) the assessment score in each area should range from 1 to 5.

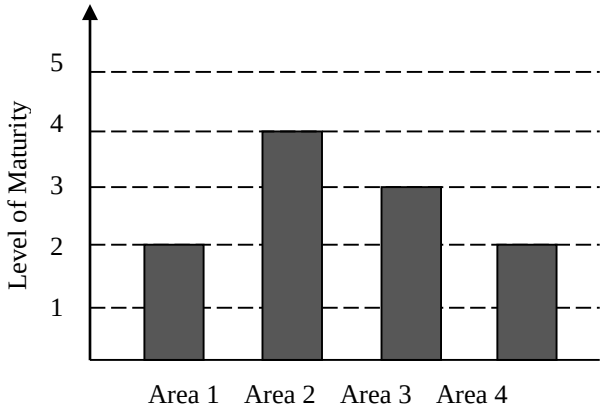

Figure 2. The major assumptions of the conceptual model

The following areas should be taken into consideration for assessment: (1) human resources, (2) methods & tools, (3) project environment and (4) knowledge management.

Table 2. The areas of maturity assessment and its components.

ID	Area	Description
1.	Human Resources	staffing, career paths, motivation, training, teamwork
2.	Methods & Tools	methods, tools, techniques and means used for project planning and execution; risk, requirements, scope, costs, time and quality management
3.	Environment	organizational structures, top management support, stakeholder management, company culture
4.	Knowledge Management	Lessons-learned approach, gathering data and experiences for on-going operations and future references

Each area includes different sets of skills/knowledge/processes/procedures (Table 2):

The *human resources* area includes all activities related to the staff required in projects, their development and management.

The *methods & tools* area includes methods, tools, techniques and means used for managing different processes and areas of managing the projects.

The *environment* area is about the organizational context in which the project operates. It also reflects the common understanding of the importance of project management for the company.

The *knowledge management* area is focused both on the technical and non-technical skills needed to support project management activities and includes data storage, distribution and management.

The five-stage level of maturity reflects the overall compliance with the best practices and could be summarized as follows: (1) *Level 1* – shows that the company is at the initial phase with barely any knowledge of processes related to project management, (2) *Level 2* – says that the company has defined standards in project management and applies them to some of its activities, (3) *Level 3* – shows that the company has defined standards in project management and applies them in the majority of its activities, (4) *Level 4* – at this level, the company recognizes and applies project management standards in all its activities, (5) *Level 5* – is the highest stage of maturity, meaning that the company is continuously searching for improvements in its project management processes. We propose naming levels 1 to 5 accordingly: *Initial, Standardized, Appliance, System Management, Self-improvement.* Detailed descriptions of the maturity levels are shown in Table 3.

Table 3. The descriptions of maturity levels in given areas of maturity assessment.

		AREA			
		Human Resources	Environment	Methods & Tools	Knowledge Management
MATURITY OF THE COMPANY	LEVEL 5 *Self-improvement*	System self-improvement	System self-improvement	System self-improvement	System self-improvement
	LEVEL 4 *System Management*	The common application of standards	Management and Organizational System completely supporting Project Management	Standard methods, tools and techniques applied to all project activities	Complex Knowledge Management system
	LEVEL 3 *Appliance*	The standards applied in most cases	Management and Organizational System supporting in majority of the activities supporting Project Management	Standard methods, tools and techniques used in the majority of activities	Knowledge Management covering the majority of fields
	LEVEL 2 *Standardized*	Standards for Human Resources defined. Their application is limited	Management System partially supporting Project Management in the company	Standard methods and tools defined or adopted for common usage in the company. Their application is limited	Knowledge Management standard defined. However, limited to some fields

	LEVEL 1 *Initial*	Standards for Human Resources management not defined	No Management system supporting Project Management in the company	Standard methods and tools not defined or adopted for common usage in the company	Knowledge Management standard not defined

As mentioned above, each area should consist of components that could be described as best practices, processes and procedures, which, if applied by the company, will result in a higher overall score in the assessed area. However, it is recommended that apart from the statistical methods applied (e.g. mean value), calculation of the specific thresholds should be met to allow the company to be classified at a higher level. Therefore, the proposed algorithm for the level assessment should include both the statistical and thresholds systems, as shown in Figure 3.

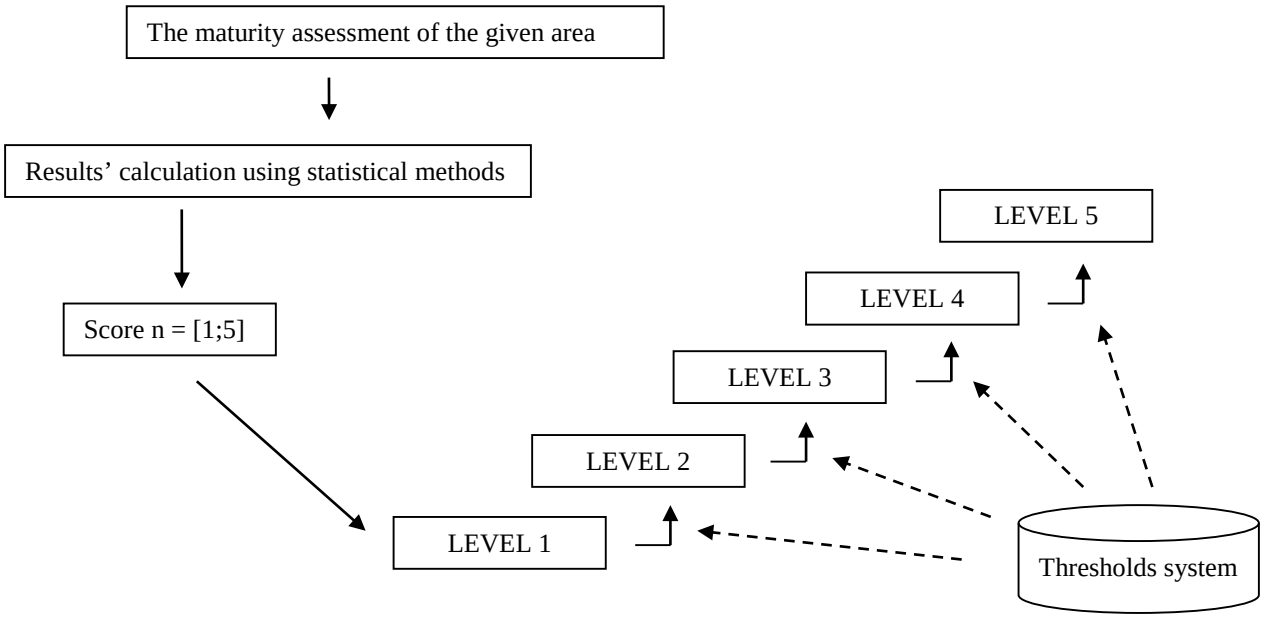

Figure 3. The conceptual algorithm for assessing the maturity level in the company

3. INDUSTRY APPLICATION

In order to definitively the utility of the model in the industrial environment in the second step, a web-based survey in the machinery industry companies was conducted. We assessed the maturity level in a simplified way, desired by the machinery industry, the following measures were used:
basic (M_p), detailed (M_d), and self-improvement (M_s). Using three types of measures allows the reduction of time needed to perform the assessment to an acceptable level by industrial companies for non-matured companies (Level 1) and the need to use different measures for over-performing ones (Level 5).

The instrument was validated using Cronbach's Alpha and then, for each testing area, the maturity level was assigned.
The algorithm itself is based on three measures (M_p, M_d, M_s): share (u), mean value ($\bar{x}$) and median (m).
Share (u) is calculated as follows:

$$u(M_p) = \frac{\sum V(M_{pi})="1"}{n} \times 100\%, \text{ where: } i = 1 \dots n, \text{and value of } M_{pi} \text{ - } V(M_{pi}) = \{0,1\}. \quad (1)$$

Mean value ($\bar{x}$) is calculated as follows:

$$\bar{x}\,(M_d) = \frac{\sum V(M_{di})}{n}, \text{ where: } i = 1 \dots n, \text{and value of } M_{di} \text{ - } V(M_{di}) = \{1,2,3,4\}. \quad (2)$$

Median (m) is calculated as follows:

when n is even:

$$m(M_d) = \frac{V(M_{d\frac{n}{2}}) + V(M_{d\frac{n}{2}+1})}{2}, \quad (3)$$

when n is odd:

$$m(M_d) = V(M_{d\frac{n+1}{2}}), \quad (4)$$

where: n is the number of M_d being part of a set, sorted incrementally by value $V(M_{di})$, where $i = 1 \ldots n$; $V(M_{di}) = \{1, 2, 3, 4\}$.

In the model, the measure u can assume a value from 0% to 100%, while the mean value ranges from 1 to 4. For each measure u, $\bar{x}$ i m, we can define the threshold values: $P_{u(p)}$; $P_{x(d1)}$; $P_{x(d2)}$; $P_{x(d3)}$; $P_{x(d4)}$; $P_{m(d1)}$; $P_{m(d2)}$; $P_{m(d3)}$; $P_{m(d4)}$ and $P_{u(s)}$, which will be used in the assessment of maturity levels using conditions (W). For conditions W1...W5, the following were presumed in the model:

W1 = „N", when $u(M_p) < P_{u(p)}$
W1 = „Y", when $u(M_p) \geq P_{u(p)}$
W2 = „N", when $u(M_p) < P_{u(p)} \vee m(M_d) < P_{m(d1)} \vee \bar{x}(M_d) < P_{x(d1)}$
W2 = „Y", when $u(M_p) \geq P_{u(p)} \wedge m(M_d) \geq P_{m(d1)} \wedge \bar{x}(M_d) \geq P_{x(d1)}$
W3 = „N", when $u(M_p) < P_{u(p)} \vee m(M_d) < P_{m(d2)} \vee \bar{x}(M_d) < P_{x(d2)}$
W3 = „Y", when $u(M_p) \geq P_{u(p)} \wedge m(M_d) \geq P_{m(d2)} \wedge \bar{x}(M_d) \geq P_{x(d2)}$
W4 = „N", when $u(M_p) < P_{u(p)} \vee m(M_d) < P_{m(d3)} \vee \bar{x}(M_d) < P_{x(d3)}$
W4 = „Y", when $u(M_p) \geq P_{u(p)} \wedge m(M_d) \geq P_{m(d3)} \wedge \bar{x}(M_d) \geq P_{x(d3)}$
W5 = „N", when $u(M_p) < P_{u(p)} \vee m(M_d) < P_{m(d4)} \vee \bar{x}(M_d) < P_{x(d4)} \vee u(M_s) < P_{u(s)}$
W5 = „Y", when $u(M_p) \geq P_{u(p)} \wedge m(M_d) \geq P_{m(d4)} \wedge \bar{x}(M_d) \geq P_{x(d4)} \wedge u(M_s) \geq P_{u(s)}$

The following thresholds were assumed, based on the outcomes from testing the framework in the industrial environment:

- Pu(p) = 50%,
- Px(d1) = 2,
- Px(d2) = 2,7,
- Px(d3) = 3,4,
- Px(d4) = 4,0,
- Pm(d1) = 1,
- Pm(d2) = 2,
- Pm(d3) = 3,
- Pm(d4) = 4,
- Pu(s) = 80%.

The model above was implemented for the purposes of project management maturity assessment in companies in the machinery industry. The invitation to participate in the study was distributed to more than 500 companies. The invitation was also posted on the websites of international organizations in project management: Project Management Institute (PMI) and International Project Management Association (IMPA). As a result of the world-wide web-based questionnaire study, validated data from 112 machinery industry companies were gathered. The companies were from different countries, with the majority from the USA (16%), Germany (16%), Denmark (12%), Sweden (12%), Italy (10%), Switzerland (9%). The other companies were from Finland, the UK, Japan, France, Austria and Ireland.

The vast majority (99%) of investigated companies reported revenue of over 2 million EURO (or approx. $2.5 million), as shown in Figure 5.

Cronbach's Alpha reported values of over 0.8 for each testing area: (1) human resources, (2) methods & tools, (3) environment and (4) knowledge management. The results revealed that there are differences between maturity levels in assessment areas and among the companies. The descriptive data are shown in Table 4.

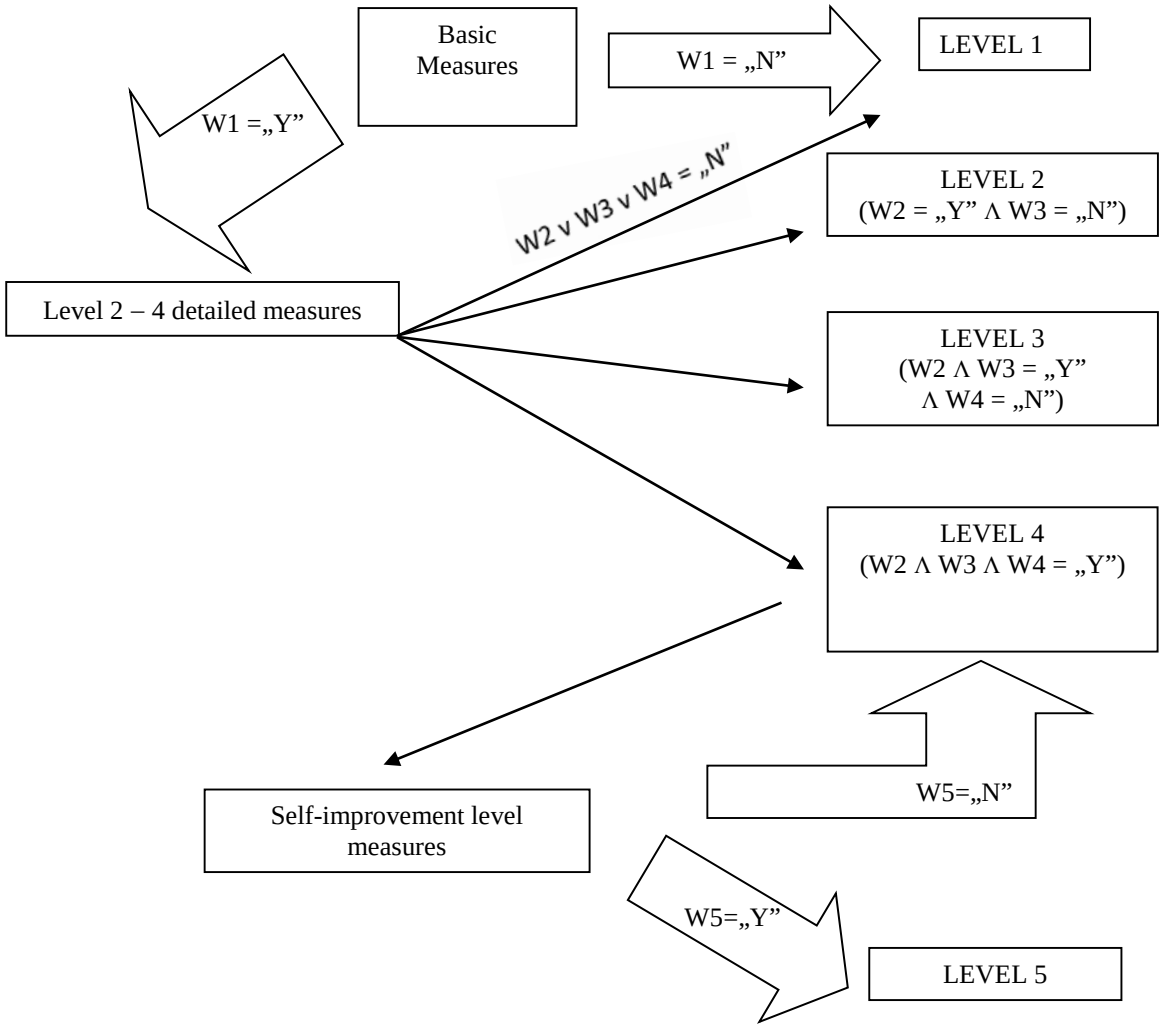

Figure 4. Applied algorithm for assessing the maturity level in the company

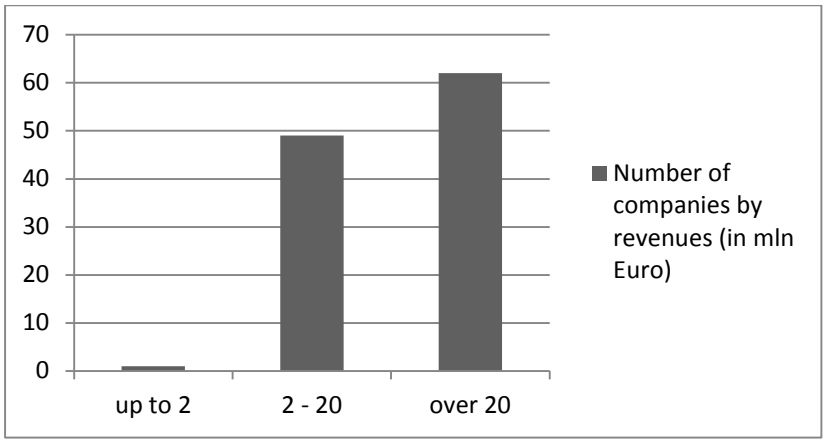

Figure 5. The number of companies in the machinery industry by revenue level

Table 4. Descriptive statistics of maturity levels by assessment area: methods and tools (M), human resources (H), project environment (E) and knowledge management (K).

Assessment area	M	H	E	K
Mean	2.5	3.34	2.27	2.18
Median	2	3	2	2
Std. dev.	0.6	0.96	0.68	0.45
Min.	2	1	2	2
Max.	5	5	5	5

The results of the study showed that the majority of companies in the investigated machinery industry exhibit approximately the second and third levels of maturity in each testing area. This result is somehow similar to the studies in the other industries, which use more demanding models (Brookes et al., 2014), and therefore proved that a simplified method of maturity assessment can be successfully used by companies in practice. It also supported the importance of measurement of knowledge management as a separate area. The results clearly showed that companies in the machinery industry should take steps to improve their capacity for knowledge management, as it is considered as the least matured at the moment.

4. CONCLUSION

The time to market is a crucial issue in the development of new products (Chen & Wang, 2009; Kyriakopoulos, 2011; Mortensen, Harlou, & Haug, 2008). Moreover, modern industrial companies are completing more projects yearly than ever before (Aubry et al., 2010; Ika, 2009; Schmidt, Sarangee, & Montoya, 2009). This means that there is a need to increase their project management efficiency. The increase can be accomplished if the company knows in which areas it is doing well and in which areas there is still room for improvement. Therefore, there is an issue of systematic assessment of their maturity level in project management. However, there are a number of project management maturity models, but they are, in most cases, hard to use due to their complexity. Moreover, there is a need to distinguish the extremely important area of knowledge management in the assessment.

We propose the new conceptual model designed for and based on the feedback from industrial companies. The model allows the assessment of project management maturity in four areas: (1) human resources, (2) methods & tools, (3) environment and (4) knowledge management. The components of the first three areas are proposed based on the reviews of literature of existing models, while the fourth one additionally includes knowledge management issues, which were somewhat covered in the other areas in the existing maturity assessment models.

As a result of the assessment, we receive a score that could be assigned to one of the five pre-defined *levels of maturity*: (1) Initial, (2) Standardized, (3) Appliance, (4) System Management and (5) Self-improvement.

Level 1 conveys that the company is at the initial phase and the application, if any, of project management is chaotic rather than systematic. *Level 2* says that the company has determined or developed the set of standards that will be used in the company when managing the projects. Moreover, it means that the common vocabulary system is used. However, the application of the standards is limited. At *Level 3*, the company applies assumed standards in the majority of its activities. However, there is still room for improvement. *Level 4* means that the standards are used across all activities related to the management of projects in the company. *Level 5* is the highest stage of maturity. At this level, the company demonstrates the capacity for self-development for the continuous improvement of the processes supporting project management in the company.

We proposed a simplified assessment model that was tested and positively assimilated by participating companies due to its less time-consuming approach, while the results of the assessment proved valuable to the companies. Moreover, through its simplicity, it can be more efficiently used in quantitative studies, while the practical application of existing models was mostly limited to the qualitative or in-depth case-studies, through their complexity and awkward implementation. Therefore, the proposed model can be used in further research in the companies on a global scale in order to assess their maturity levels and perform cross-comparative industrial studies.

Based on the level of maturity a company exhibits in a chosen area, it receives feedback on how well it is performing and if there is room for further improvement and, if necessary, additional in-depth studies are conducted using more complex existing maturity assessment models.

Finally, the results will help us to understand the current state of project management and could be used by participating companies as feedback in their efforts to increase efficiency levels in project management.

4. ACKNOWLEDGMENT

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REFERENCES

Adams-Bigelow, M., Kleinschmidt, E. J., Kuczmarski, T. D., Notargiacomo, R., & Peters, L. S. (2006). Rejoinders to "Establishing an NPD best practices framework". *Journal of Product Innovation Management, 23(2),* 117-127.

Allenbach, R. L., & Huffman, J. E. (2000). Improving simulation engineering practices II - A management-by-deliverable approach for simulation project management. [Article]. *International Journal of Industrial Engineering-Theory Applications and Practice, 7*(2), 115-122.

Aubry, M., Hobbs, B., Muller, R., & Blomquist, T. (2010). Identifying Forces Driving PMO Changes. *Project Management Journal, 41*(4), 30-45.

Becker, J., Knackstedt, R., & Poppelbuss, J. (2009). Developing Maturity Models for IT Management - A Procedure Model and its Application. *Business & Information Systems Engineering, 1*(3), 213-227.

Bernardo, C. I., Angel, M. R., & Eloisa, G. R. M. (2011). Dgam Methodology To Design A Knowledge Management System. *International Journal of Industrial Engineering-Theory Applications and Practice,* 18(2), 103-108.

Besner, C., & Hobbs, B. (2008). Discriminating Contexts and Project Management Best Practices on Innovative and Noninnovative Projects. *Project Management Journal,* 39, S123-S134.

Brookes, N., Butler, M., Dey, P., Clark, R. (2014). The use of maturity models in improving project management performance: An empirical investigation. *International Journal of Managing Projects in Business,* 7(2), 231 – 246.

Buch, M. S., Edwards, A., & Eriksson, T. (2009). Participants' evaluation of a group-based organisational assessment tool in Danish general practice: the Maturity Matrix. *Qual Prim Care, 17*(5), 311-322.

Caprioara, M. F., & Paraschivescu, A. O. (2009). Project Management Between The Crisis Of Economic Solutions And The Economic Solutions Of Crisis. *Metalurgia International, 14*, 154-157.

Chen, Z., & Wang, L. (2009). Adaptable product configuration system based on neural network. *International Journal of Production Research,* 47(18), 5037-5066.

Cho, K. K., & Moon, B. K. (2006). A method for selecting the optimal portfolio of performance improvement projects in a manufacturing system. *International Journal of Industrial Engineering-Theory Applications and Practice, 13*(1), 61-70.

Cho, Y. K., Moore, J. T., & Hill, R. R. (2003). Developing a new greedy heuristic based on knowledge gained via structured empirical testing. *International Journal of Industrial Engineering-Theory Applications and Practice,* 10(4), 504-510.

Cooke-Davies, T., Schlichter, J. and Bredillet, C. (2001). Beyond the PMBOK guide, *Proceedings of 32nd Annual Project Management Institute*. Seminar Symposium. Nashville, TN.

Crawford, J. K. (2006). The project management maturity model. *Information Systems Management, 23*(4), 50-58.

Friesl, M., Sackmann, S. A., & Kremser, S. (2011). Knowledge sharing in new organizational entities The impact of hierarchy, organizational context, micro-politics and suspicion. *Cross Cultural Management-an International Journal,* 18(1), 71-86.

Gasik, S. (2011). A Model of Project Knowledge Management. *Project Management Journal,* 42(3), 23-44.

Gorschek, T., Gomes, A., Pettersson, A., & Torkar, R. (2012). Introduction of a process maturity model for market-driven product management and requirements engineering. *Journal of Software-Evolution and Process, 24*(1), 83-113.

Grant, K. P., & Pennypacker, J. S. (2006). Project management maturity: An assessment of project management capabilities among and between selected industries. *IEEE Transactions on Engineering Management, 53*(1), 59-68.

Ha, X. X., & Lv, W. X. (2006). The roles of project management office on the basis of Project Management Maturity Model (ID : 5-019). *Proceedings of the 13th International Conference on Industrial Engineering and Engineering Management, Vols 1-5*, 1719-1723.

Hammer, M. (2007). The process audit. *Harvard Business Review, 85*(4), 111-132.

Hillson, D. (2003). Assessing organizational project management capability. *Journal of Facilities Management,* Vol 2, No 3, PP 298-311.

Ika, L. A. (2009). Project Success as a Topic in Project Management Journals. *Project Management Journal,* 40(4), 6-19.

ISIC. (2008). International Standard Industrial Classification of All Economic Activities, ISIC, *Statistical Papers Series M No. 4/Rev.4*. New York: Department of Economic and Social Affairs Statistics Division, United Nations.

Jasemi, M., Kimiagari, A. M., & Memariani, A. (2011). A Conceptual Model For Portfolio Management Sensitive To Mass Psychology Of Market. *International Journal of Industrial Engineering-Theory Applications and Practice,* 18(1), 1-15.

Jia, G., Chen, Y., Xue, X., Chen, J., Cao, J., & Tang, K. (2011). Program management organization maturity integrated model for mega construction programs in China. *International Journal of Project Management,* 29(7), 834-845.

Kahn, K. B., Barczak, G., & Moss, R. (2006). Perspective: Establishing an NPD best practices framework. *Journal of Product Innovation Management,* 23(2), 106-116.

Kamrani, A. K., Adat, A., & Azimi, M. (2011). A Methodology For Analysis Of Manufacturing Operations Due To Complexity. *International Journal of Industrial Engineering-Theory Applications and Practice,* 18(2), 71-82.

Kalantjakos, N.J., (2001). Assessing organizational project management maturity. *Proceedings of 32nd Annual Project Management Institute*. Seminar Symposium. Nashville, TN.

Kerzner, H. (2001). *Strategic Planning for Project Management Using a Project Management Maturity Model*. New York: Wiley.

Khoshgoftar, M., & Osman, O. (2009). *Comparison of Maturity Models*. New York: Computer Science and Information Technology, ICCSIT 2009. 2nd IEEE International Conference.

Kwak, Y., H. (2000). Calculating Project Management's Return on Investment. *Project Management Journal, 31*(2), 38.

Kyriakopoulos, K. (2011). Improvisation in Product Innovation: The Contingent Role of Market Information Sources and Memory Types. *Organization Studies,* 32(8), 1051-1078.

Lai, W.-H. (2011). Corporate Firm-Level Knowledge Accumulation And Engineering Manpower Outsourcing. *International Journal of Industrial Engineering-Theory Applications and Practice,* 18(4), 191-202.

Lee, J. Y., Lee, D. Y., & Kang, S. W. (2007). An Overview of the Business Process Maturity Model (BPMM). *Advances in Web and Network Technologies, and Information Management, Proceedings, 4537*, 384-395.

Lin, C., Lin, H.-C. K., Huang, Y.-A., & Jalleh, G. (2011). The fit between organizational B2B e-commerce policy, IT maturity and evaluation practices on B2B e-commerce performance in Australian healthcare organizations. *African Journal of Business Management*, 5(5), 1983-2005.

Liu, X. Q., Ma, S. H., & Li, W. (2004). *Activity-based costing and construction project performance improvement*. Beijing: Baiwanzhuang Xichenggu.

McBride, T., Henderson-Sellers, B., & Zowghi, D. (2004). Project management capability levels: An empirical study. *11th Asia-Pacific Software Engineering Conference, Proceedings*, 56-63.

Metikurke, S., & Shekar, A. (2011). An Empirical Study Of Important Dimensions Of New Product Development Practices In Small And Medium Enterprises In New Zealand. *International Journal of Industrial Engineering-Theory Applications and Practice, 18*(2), 83-91.

Mortensen, N. H., Harlou, U., & Haug, A. (2008). Improving Decision Making In The Early Phases of Configuration Projects. *International Journal of Industrial Engineering-Theory Applications and Practice, 15*(2), 185-194.

OGC. (2006). *PRINCE2 Maturity Model (Version 1.0)*. London, UK: Office of Government Commerce.

Paulk, M.; Weber, C.; Curtis, B.; Chrissis, M. (1993). "Capability Maturity Model for Software, Version 1.1". *Technical Report* (Carnegie Mellon University / Software Engineering Institute). CMU/SEI-93-TR-024 ESC-TR-93-177. http://www.sei.cmu.edu/library/abstracts/reports/93tr024.cfm. (Accessed October 2011).

PMI. (2008). Organizational Project Management Maturity Model (OPM3®), Knowledge Foundation - 2nd Edition (pp. 204). Newtown Square, PA, USA: Project Management Institute.

Project Management Institute (2008). *Organizational Project Management Maturity Model (OPM3®) Knowledge Foundation - 2nd Edition*, USA, PA: Author.

Relich M., & Muszynski W. (2014). The use of intelligent systems for planning and scheduling of product development projects. *Procedia Computer Science*, vol. 35, pp. 1586-1595.

Rowley J., *Using Case Study in Research*, Management Research News 2002, 25 (1), 16-27.

SCAMPI upgrade team, Standard CMMI Appraisal Method for Process Improvement (SCAMPISM) A, Version 1.2: Method Definition Document. *CMU/SEI-2006-HB-002*. Software Engineering Institute. 2006. http://www.sei.cmu.edu/library/abstracts/reports/06hb002.cfm. (Accessed December 2014).

Schmidt, J. B., Sarangee, K. R., & Montoya, M. M. (2009). Exploring New Product Development Project Review Practices. *Journal of Product Innovation Management*, 26(5), 520-535.

Shi, J., & Jia, H. (2009). *Innovative Research of Engineering Project Management on BT Mode Under Financial Crisis*. Marrickville: Orient Acad Forum.

Shida, K., Yamamoto, N., Matsumoto, T., & Kanazawa, T. (2007). Development of a training program on inventory and information systems. *International Journal of Industrial Engineering-Theory Applications and Practice*, 14(3), 279-288.

Spalek, S. (2014). Does Investment in Project Management Pay Off? *Industrial Management & Data Systems, 114*(5), 832-856.

Spalek, S. (2014). Finding a New Way to Increase Project Management Efficiency in Terms of Time Reduction. *Inzinerine Ekonomika-Engineering Economics, 25*(5), 538–548.

Spalek, S. (2014c). Project-based learning. Experiences from the initial stage of implementation in a higher education institution. *International Journal of Innovation and Learning, 16*(1), 1-11.

Spalek, S. (2013). *Project Management Maturity of the Company*. Monograph (513). Gliwice: Silesian University of Technology, 180.

Spalek, S. (2013). Improving Industrial Engineering Performance Through a Successful Project Management Office. *Inzinerine Ekonomika-Engineering Economics, 24*(2), 88-98.

Spalek, S. (2012). The Role of Project Management Office in the Multi-Project Environment. *International Journal of Management and Enterprise Development, 12*(2), 172–188.

Twaites, G., Collofello, J., & Zenzen, F. (2004). The CMMI - More than just process. *Tenth ISSAT International Conference on Reliability and Quality in Design, Proceedings*, 309-314.

Valdes, G., Solar, M., Astudillo, H., Iribarren, M., Concha, G., & Visconti, M. (2011). Conception, development and implementation of an e-Government maturity model in public agencies. *Government Information Quarterly*, 28(2), 176-187.

Van Rooij, S. W. (2011). Instructional design and project management: complementary or divergent? *Etr&D-Educational Technology Research and Development*, 59(1), 139-158.

Wang, C. B., Chen, Y. J., Chen, Y. M., & Chu, H. C. (2005). Knowledge refinement for knowledge management in engineering design. *International Journal of Industrial Engineering-Theory Applications and Practice*, 12(4), 378-395.

Wang, C. T., Wang, J. Y., Chu, T. H., & Chao, C. C. (2001). A BPR support for Computer-Integrated Manufacturing management. *International Journal of Industrial Engineering-Theory Applications and Practice, 8*(4), 319-328.

Wang, F. L. (2005). *Project management maturity model and its appraisal method*. Harbin: Harbin Institute Technology Publishers.

Wang, R. C., & Liang, T. F. (2006). Application of multiple fuzzy goals programming to project management decisions. *International Journal of Industrial Engineering-Theory Applications and Practice*, *13*(2), 219-228.

Watts, H. (1989). *Managing the Software Process*. Addison Wesley, Reading, MA.

Wendler, R. (2012). The maturity of maturity model research: A systematic mapping study. *Information and Software Technology, 54*(12), 1317-1339.

Zhang, L., Li, F. (2014). Risk/Reward Compensation Model for Integrated Project Delivery. *Inzinerine Ekonomika-Engineering Economics*, *25*(5), 558–567.

Zhou, M., Son, Y., Chen, Z., Zhang, Q., & Ma, J. H. (2007). Conceptual simulation modeling: Patterns and knowledge representation. *International Journal of Industrial Engineering-Theory Applications and Practice*, 14(1), 73-83.