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ASSESSING MATURITY REQUIREMENTS FOR IMPLEMENTING AND USING PRODUCT LIFECYCLE MANAGEMENT

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Abstract
Product lifecycle management (PLM) is a systematic and holistic way to approach challenges that exist in managing product related information along products' lifecycle from product design to its disposal. There is an established set of information management approaches that address important subsets of lifecycle information management challenges, e.g. product data management (PDM), ERP and CRM. Common feature to PLM processes is that their implementation requires changes in organization, systems, conventions, and importantly, skills and capabilities. The aim of this paper is to discuss the issue of PLM implementation and how it can be aided with capability maturity assessment. Empirical part of the paper points out how capability maturity assessment can be conducted and how it is applicable in different stages of implementing and developing PLM.

Keywords: Product lifecycle management (PLM), maturity models, capability maturity model (CMM), capability maturity assesment

Introduction
Product lifecycle management (PLM) is a systematic and controlled concept for managing product related information and products throughout the whole product lifecycle [1]. The benefits gained by using PLM in the different separate phases of product lifecycle are proved by many sources, but utilizing product information together with other information types (like customer information) sets challenges for the lifecycle management (see e.g. [2],[3]), for example, combining historical information of maintenance to predicted customer needs would ease the decisions of product customization. PLM covers various types of product-related information from product design and manufacturing all the way to the end of use, after sales and service phases, as well as to the end of the lifecycle, to the scrapping of the product. Information management during the whole product lifecycle is important, and furthermore, utilizing information from multiple different operational sources and the sharing of information to support the decision making in different stages are strongly emphasized from product lifecycle management perspective.

There are several reasons why PLM and competency or capability management practices (such as maturity models) should be linked together. First, the implementation of PLM in an organization is a very extensive change process which cannot be carried out in a single step, but should be divided and managed in a series of smaller stages. It requires various changes not only at the IT systems level, but often also at the strategic level, and at the process level, and further, at the level of reward and incentive systems and individual persons' skills and capabilities. Second, the above-mentioned changes should be carefully planned together and coordinated – due to the complex, systemic and organization-wide nature of PLM activities and systems, a single change in PLM- related IT systems, such as customer relationship management (CRM) systems, requires carefully synchronized and often simultaneous changes in related personnel skills and competences, processes and incentive systems.

According to various studies concerning the knowledge accumulation in companies and their business processes (e.g., [4],[5],[6], knowledge development and accumulation in organizations can be categorised and described in distinct phases or stages. Models that are used to describe the afore-mentioned development phases are usually called 'maturity models'. Maturity models can be characterized as special types of roadmaps for implementing practices in an organization, and their purpose is to help in the continuous improvement of the capabilities of an organisation in certain application or management areas, such as software development [7], R&D [8], and process development [6].

In order to be able to assess and develop the knowledge maturity stages, the aggregate knowledge area needs to be disaggregated to manageable management attributes. In line with the maturity-level thinking, the development related to these management attributes should proceed more or less parallel from one maturity stage to the next (see e.g. [9]).

PLM- related maturity models can be thought to consist of maturity stages describing the

knowledge or capability levels of PLM maturity, as well as the PLM- related business dimensions, which are the critical knowledge or capability areas the maturity of which should be measured and the development of which should be coordinated and planned together.

Academic PLM- related research is, generally speaking, relatively young, and so far hardly addressed in scientific literature. According to literature study covering practically all published academic PLM literature, as well as PDM (product data management) literature, first, there are very few studies that discuss maturity model or roadmapping approaches in context with PLM implementation. Second, the literature discussing the use of not only one but several business dimensions in the context of PLM roadmapping or maturity assessment was practically non-existent. Concerning the maturity levels, the carried out literature study revealed that one relatively commonly used maturity assessment procedure in PLM context was based on CMM /CMMI (capability maturity model) literature, the origin of which is in software maturity evaluation. Following this tradition, typically, in literature is found [1] that in PLM maturity models, there were 5 PLM maturity levels, from 1 (unstructured) to 5 (optimal). Concerning the business levels, the evaluation of PLM maturity was most commonly carried out in respect of only one generic dimension, as a one-dimensional roadmap, and we found very few academic studies that included more than one business dimension in the PLM maturity evaluation, including the studies of Batenburg et al.[10],[11].

The aim of the paper is to, both theoretically and empirically, examine how organizational maturity has been, can be and should be assessed in order to successfully implement and development product lifecycle management scheme. Theoretical part consists of a literature review concerning PLM and maturity model literature. Empirical study included in the paper emphasizes and clarifies the importance of maturity assessment before and during the PLM implementation process. Moreover, two cases from the manufacturing industry shed light on the topic from the perspective of praxis. Using maturity models or road maps in order to implement certain activities or to make an organizational change can be seen closely related to competency or capability assessment; therefore there is also a close link to knowledge management (KM) research. Correspondence between maturity models and competency assessment is studied in order widen the domain of managerial implications.

Main notions on using maturity assessment along the PLM process are to make the implementation of the extensive business issue of PLM better approachable and a more carefully planned process, since a significant portion of companies struggle heavily in the adoption and implementation of PLM (see e.g. [10]), and to avoid premature moves, which is to say to avoid implementing processes or systems in to an organization that is not yet able to utilize them. Different maturity levels can be comprehended as gates, i.e. development should be in parallel and simultaneously coordinated in every business dimension. Such an approach is also likely to reduce the costs and the duration of PLM implementation.

Deployment of product lifecycle management

Key challenge in any implementation process can be seen via organizational readiness, say maturity, to change the way it operates. When beginning a change in organization or processes the first threshold is to answer the question: "Is our organization willing and/or able to deploy a new operating procedure." Testing willingness is somewhat easy, as if there is a need then there is will too. Several authors (e.g. [12], [11, 335], [13 41] refer to organizational and individual capabilities as a major key success factor in development process. Lack of capabilities can inhibit or even halt the process.

Developing PLM requires a large set of changes, not only on level of systems, but also on skills and competences, procedures and mental setting. In order to deploy a single change in operation synchronous and indented changes are required processes, skills of the personnel, in organization, assessment systems and motivation system. Moreover, the "eye should be kept on the ball", i.e. adjustments are often conducted step by step along each other. There are two general ways to approach change process. Firstly, by drawing a "road-map" with milestones needed or secondly, by refining the map by adding content to each milestone. Content is added by assessing ability to proceed.

As stated by [14, 73] capability assessment and knowledge management, in this case management of skills and abilities, play somewhat similar role in development schemes. Key question is how to take in account dynamics that is implicit part of knowledge accumulation in development. As stated by Niemi et al. (2008) change is aided by utilizing suitable competencies, i.e. it is normal that practices and technology need to evolve along the way. To put it short, what is desirable stage and setting in initial phase, can be non-functional in latter phases. Maturity assessment helps to put focus on key competencies as it has systematic and analytical operations model of recognition and measurement. Moreover, if assessment process is complete, it

should also contain set of correcting actions if any malfunctions are perceived.

In order to measure capabilities a measurement framework is needed. CMMI is an established way to asses required capabilities and capability levels [13, 213]. Batenburg el al. [11, 346-347] states that PLM implementation requires a roadmap that is an integrative plan for implementation. Capabilities and capability management can also seen as an integral part of (any) implementation process [16]. According to Niemi et al [16] there should be defined certain maturity stages and attributes of technology adaption. Sääksvuori & Immonen [1] defines a "one-dimensional" maturity model that takes in account the working practices, i.e. maturity levels, of PLM in general. To put more sense to assessment it should be refined by more elaborated PLM maturity assessment framework such as one described by Batenburg et al [10] that takes in account also different business dimensions.

Despite of which dimensions or maturity levels are chosen management of capabilities and skills are essential [17, 287-288]. In general, capabilities can be considered as an organizational attribute or an organizational view. Skills are closed aligned to people in organization, thus personnel view. E.g. Kneuper [12, 19-21] describes way to operationalise assessment task. Operationalisation is done by defining desired or assumed maturity levels in chosen business dimensions. Business dimensions refer to certain operational positions. By Batenburg et al (2005) positions are *strategy and policy, organization and processes, people and culture and information technology*. Translating this to 'general assessment language', PLM maturity assessment requires views, success factors and performance indicators.

Batenburg et al [10] justifies mentioned business dimensions for PLM by an empirical study. Dimensions cover different practices and stakeholders that are connected to PLM and its subprocesses. Holistic view to PLM is needed in order to avoid fading the idea of PLM only to level of product data management. Batenburg et al [11] states that PLM maturity assessment should be seen via several dimensions, especially aligning business and IT. Batenburg at al (ibid.) points out several similarities in different maturity assessment models, yet chosen model is well grounded in theory and empirically validated.

According to Dayan & Evans [14, 74] maturity assessment e.g. in PLM by CMM/CMMI is done recognizing key performance indicators (KPIs) or goals in each process area or position. Each KPI is operationalised to measureable indicators that are connected to specific practices or general practices. Batenburg at al. [10] assessment framework is chosen as analysis framework in the empirical part of this paper. Baterburg et al [10] framework emphasizes balanced development in each business dimension (See Appendix 1).

Case study of two manufacturing companies
Case company descriptions
The studied companies will be called here EngCo1 and EngCo2. Both companies are Finnish Finland-based engineering companies that belong to the metal industry, and they work in business-to-business markets. They produce e.g. relatively complex process solutions for the process industry companies, requiring much information and sophisticated understanding of customers' businesses. They strive at close cooperation with their customers, aiming also for close partnerships and comprehensive customer solutions. Even though producing technology products and solutions has been their main business, services including long-term service contracts has been an area for fast development. The companies have been operating for decades, and they belong to technology and/or market leaders within their industries.

EngCo1 is a daughter company of a medium-sized Finnish company with about 250 employees. It is operating mainly in Finnish markets, and there are about ten persons working in the case company. It operates in a project business where it customizes each delivery according to customer requirements.

EngCo2 is a company operating in Finnish and international markets, including offices in dozens of locations worldwide. It has around 500 employees and its turnover is ca. 100 Million euros.

Product lifecycle management implementation objectives

EngCo1 is a company with long history in PDM but the concept of PLM is a relatively fresh one. Its aims for PLM implementation include defining a PLM strategy, understanding the principles of PLM, setting a two-year development target for PLM and building a roadmap for the achievement of the target.

EngCo2 has worked with PLM for some years, and its PLM aims include the holistic facilitation of PLM in order to lengthen and widen customer relationships, the facilitation of partnerships, and the improvement of service business in a holistic manner.

In order to facilitate the companies' PLM implementation and adoption, a PLM maturity assessment was carried out in both companies. The following results are derived from the expert assessment in the two companies, including IT and management evaluations and interviews.

Maturity assessment process and generic maturity results

The maturity assessment was conducted according to Batenburg et al. [10] (see appendix 1) model. In practice the evaluation was done by a simple scoring method in which each question concerning the individual topics of the 5 x 8 matrix was scored from 0 to 4. Levels of maturity and scores of each question varied from non-existing (0), ad hoc (1), departmental (2), organizational (3) to inter-organizational (4). Assessment result for each business dimension is average score of eight questions

Figures 1 and 2 summarize the assessment result in a graphical form. On the basis of the maturity

assessment, both the companies are relatively low in the business dimensions of the PLM maturity assessment. This is fully understandable because of their relatively short PLM history. EngCo2 has a longer history in PLM, which shows in the overall scores of the evaluation. Both the companies scored lowest in the Information technology and People and culture dimensions. Both scored highest in Monitoring and control and Strategy and policy dimensions. Organization and processes –dimension was somewhere in between these two polar dimensions.
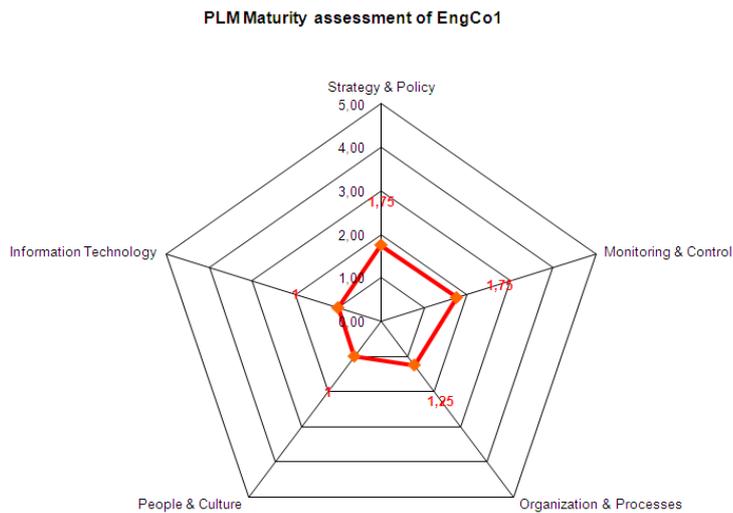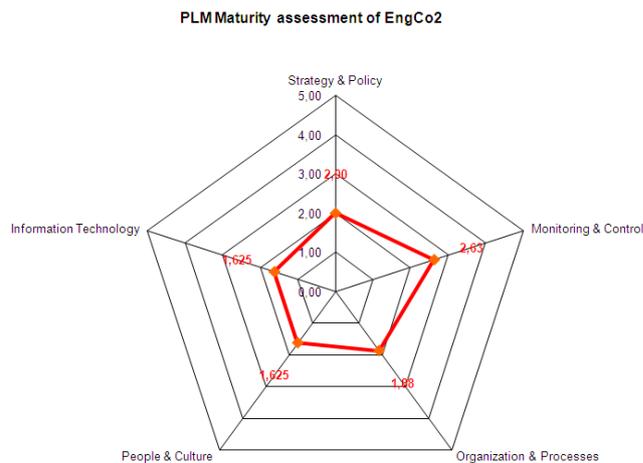

Figure 1 PLM maturity assessment results of

EngCo2
Figure 2 PLM maturity assessment results of EngCo2

Case companies' evaluation of development needs for the whole PLM maturity assessment framework

The evaluation was conducted by utilizing the expertise of company persons representing two functions, IT and general management. As pointed out in literature review business/IT-alignment is important.

EngCo1 represents SME view as resources are more limited and awareness on PLM issues, other than PDM, is in very early stage. EngCo2 has already established PLM procedures and it has different approach to assessment. In EngCo2 current status is due to the resources of the company and higher level of understanding on the issue. It could be stated that EngCo2 represents the developmental phase of PLM. Key question is to find out what are the aims for PLM initiatives in both cases and refine maturity assessment model according to those. As maturity assessment model is rather generic, both case companies implied need for elaborating the model in order to better meet their needs.

EngCo1 has typical development challenges of small company. Use of established evaluation model needs somewhat stable environment over time. How does it function in dynamic environment when object of assessment in continuous change? Limited resources are also challenge, especially when single employee has several roles, and roles change. Also unestablished company has specific challenges, e.g. financing, project management, timetables and growth management. Those factors cause turbulence which may affect the use of assessment.

Second development need was how the customers and the customer perspective are taken in account. Informants in EngCo1 found that the issues concerning customer needs or demands or customer feedback were missing. Also closer co-operation with customers in lifecycle services should be paid attention to.

EngCo2 has more general knowledge on PLM and for them it was easier to evaluate the maturity assessment model. Main outcome here, too, was that model should take the customer viewpoint more into account. Customer perspective here is to pay more attention to customership and see the effects of it.

Expressed development needs concerning the customer perspective in EngCo2 were first, how customer can affect incidents in life cycle, i.e. need for closer co-operation or even process partnership. Second, how to attach customer to design and product development? Third, to ensure if co-operation is practical, i.e. costs do not exceed benefits. And fourth, how to communicate customers' benefits of closer co-operation? Taking the perspective on PLM, especially the fourth point adds value to EngCo2 as efficient communication of benefits engages customers to PLM process as goal and benefit are communicated.

Case companies' evaluation of the development needs concerning used maturity assessment framework's individual business dimensions

Customer viewpoint

Because PLM covers not only the company itself, but the implementation of PLM has large influences towards customers, as well (the implementation of PLM should evaluate the maturity of both the company and the customer for the changes in processes and operation procedures etc.), the case companies experienced that the maturity framework and the included five business dimensions should also take the customer viewpoint somehow into consideration in the maturity assessment.

The table of Appendix 2 summarizes the case companies' development suggestions or challenges concerning each of the five business dimensions. For instance, the companies noted that all the business dimensions included customer-related tasks or concerns to be considered when the companies are advancing in maturity in each of the business dimensions. In general, it was also noted in the interviews that PLM implementation and maturity advancement often requires new ways of operation from customers, as well, e.g. concerning the ways they provide information about their needs and business to their partners and suppliers. To enable these changes, it is critical that customers are aware of the significance of these changes and the benefits that customer (or even individual customer's functions) will receive when implementing new ways of operation.

Company viewpoint

We asked the case companies which kinds of development needs the case companies experienced in the business dimensions of PLM maturity framework when taking the case companies' own PLM objectives and company-based restrictions (e.g. resources) into consideration. EngCo1 emphasized the viewpoint of small project-based company towards PLM, in which e.g. IT -dedicated personnel and resources are more scarce. EngCo2 considered the development needs from a larger international company's standpoint.

The table of Appendix 3 summarizes the case companies' development suggestions or challenges concerning the five business dimensions.

On the basis of the interviews, both the companies felt that the maturity assessment suffered somewhat e.g. in the case of Information technology business dimension from the fact that the used IT was not a real extensive PLM solution, but consisted

of individual IT solutions that need to be integrated in various ways. The IT dimension also affected the other dimensions, such as the roles and responsibilities in IT use etc. This brought out the systemic nature of PLM implementation: all the various individual business dimensions have close links to almost all the other dimensions, and in the course of the advancement in the maturity steps these links should be carefully taken into consideration and the maturity advancing development tasks should be intensively coordinated.

Case companies' viewpoints on the usefulness of PLM maturity framework and maturity evaluation

In the general sense, the evaluation framework was experienced to provide an illustrative way to support the implementation of PLM in the studied companies. It provided a way to divide a huge entity, PLM, to more manageable pieces (EngCo1), a holistic picture of how PLM (implementation) touches and influences different company functions, all organizational levels and also customers (EngCo2), a model that enables to better take the whole product lifecycle into consideration from design to scrapping (EngCo2). It also provided a way to understand better the next steps and future tasks, as well as when and in which order of procedure to proceed, and understand why to proceed in this way (EngCo1).

Concerning collaboration and coordination of information exchange between company personnel and functions, the maturity evaluation was experienced to emphasize the importance of information and knowledge exchange (EngCo2), to give a starting point for the creation of common picture about the starting situation in the PLM implementation (EngCo1), to enable the vertical and horizontal (management, personnel and different company functions) interaction (EngCo1) and as a way to build up common motivation for the PLM facilitation (EngCo1), and it points out the most critical steps in PLM implementation and facilitation (EngCo2).

As a tool for competence management, the maturity evaluation gives a better way to understand what development actions can be done with present resources (and skills), and which resources and skills should be further developed (EngCo2). It also helped to understand whether current resources are used non-optimally or in a wrong way, and simultaneously to see whether they should be allocated differently (taking the amount of resources into consideration) in PLM implementation (EngCo2).

Conclusions

In general this study has pointed out that capability maturity assessment is a useful and beneficial tool in the implementation and development of product life cycle management scheme. As pointed out in the

cases it is useful through the lifecycle of PLM, i.e. in the initial phase it serves as a test for the possibility to implement a PLM scheme, and after implementation it serves as a tool to elaborate the scheme. In addition, multi-dimensional PLM maturity models, such as the model developed by Batenburg et al ([10], [11]) provide significant benefits in comparison with the more simplistic one-dimensional roadmaps, offering a more holistic and systemic perspective to PLM implementation that can significantly facilitate PLM implementation and the collaboration between different company functions, organizational levels and company stakeholders, most importantly, the customers.

Main outcome of this paper is that maturity assessment models are generic and applying those needs operationalisation of business dimensions and maturity levels, taking e.g. the target companies' PLM objectives, company size and resource limitations into account. In addition, according to the case companies' interviews, since PLM implementation affects closely also the customers' operation and brings changes to customers' processes, the advancement in the PLM maturity stages should take into consideration the evaluation and facilitation of the customers' maturity, as well. If these are not taken into consideration properly, the assessment does not provide sufficiently useful and applicable knowledge on PLM maturity and its development.

in addition to the above, on the basis of the case studies, the maturity assessment framework was seen as a useful tool for both competence management and development, as well as a tool for supporting collaboration and information exchange coordination.

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APPENDICES

Appendix 1: PLM issues used in the evaluation by each business dimension (Batenburg et al., 2005)

Strategy & policy	Management & control	Organization & processes	People & culture	Information technology
PLM strategy is described	Responsibility for in-time product delivery is defined	Procedures to support PLM are implemented	Task and job descriptions contain references to PLM processes/procedures	PLM software is used in the company
PLM strategy and its changes are communicated	Time-to-market of new products is monitored	PLM process descriptions are maintained	Employees raise suggestions to influence product lifecycle decisions	PLM software is integrated with other information systems
PLM strategy is aligned with the corporate strategy	Rules about cost allocation during product development are defined	PLM process descriptions are standardized	PLM training benefits the organization	PLM software includes functionality to manage product configurations
PLM strategy is evaluated	Explicit processes for quality control are defined	Product lifecycle teams are organized	Employee reward system is related to product performance throughout its lifecycle	PLM processes are automated by workflow management functionality
PLM strategy is adapted if needed	Metrics for product quality are defined	PLM procedures are formally described	Employees actively support the PLM strategy	PLM software includes functionality to manage documents
PLM strategy is translated into an action plan	Product quality after market introduction is monitored	PLM drives the product release process	Employees collaborate on product lifecycle issues	A roadmap for the implementation of new PLM software is defined
Document management is included in PLM strategy	Status of lifecycles of products is known	PLM includes a document revision process	Employees are actively involved in the implementation of PLM software	PLM software is based on compatible industry and technological standards
PLM strategy addresses the main PLM processes	Project management method for managing a product through its lifecycle is applied	PLM includes change management procedures	The concept of PLM is clearly understood	PLM software includes functionality to manage product changes

Appendix 2

What kinds of development needs did the case companies experience in the business dimensions of PLM maturity framework in taking the customer perspective into consideration?		
Business dimension	**EngCo1**	**EngCo2**
Strategy & Policy	Customers' requirements and feedback should be at least as important part of PLM strategy as document management.	Future customer needs should affect the facilitation of PLM; for example, are new resources needed (acquired/developed) for e.g. customer need acquisition in the future?
Monitoring & Control	There should be added questions concerning customer requirement handling, and monitoring and controlling the level of customer service.	The launching of novel products should be taken into consideration in management.
Organization & Processes	The processes concerning customer requirement handling and customer feedback are important. Also, the links to quality systems should be considered, since role definitions and operating procedures are part of them. "PLM-procedures" is a very generic and abstract expression in the evaluation topics.	Customers should be aware of the various responsibilities and roles of different actors (companies, company functions, individual persons) during the product lifecycle. E.g. if the sales is the only customer interface towards customers, the customer feedback and inquiries reaches the right persons slowly and the information changes on the way.
People & Culture	The product lifecycle thinking and customer viewpoint should be jointly expressed in organizational culture and peoples' work tasks. Are PLM, quality systems and customer viewpoint somehow possible to be integrated (in this business dimensions)?	The sharing of process knowledge together with customers Development cooperation in the case of new products and services
Information Technology	The customer feedback from the different stages of the whole product lifecycle should be brought to use in the organization by means of IT tools.	The integration of IT systems (e.g. maintenance and product data) The usefulness should be argumented to customers

Appendix 3

What kinds of development needs did the case companies experience in the business dimensions of PLM maturity framework in taking the case companies own PLM objectives and company-based restrictions (e.g. resources) into consideration?		
Business dimension	**EngCo1**	**EngCo2**
Strategy & Policy	Additionally, the links between PLM and product/technology strategy and quality policy should be considered in the maturity assessment	Is document management necessary to be defined and evaluated in this business dimension? (possibly in Organization and processes)
Monitoring & Control	The questions are right, but the emphasis in the topics is too much in product development. In the case of project business it is difficult to understand how the quality control of the launched product can be achieved.	It is important to ensure that management supports PLM implementation It is also important to take into consideration how different company functions take PLM requirements into consideration, as well as how they understand the benefits of PLM (in different maturity stages)
Organization & Processes	Document management belongs to the basic tasks that the company has to define, but the sufficient level of related procedures is determined also by PLM objectives and procedures The management of product information and quality system should support each other and should be integrated in order not to build competing systems.	Important to consider how the customer is taken into consideration in company processes that change due to PLM implementation (e.g. increase in the number of customer interfaces)
People & Culture	When PLM is still in its infancy, the task and job descriptions do not yet necessarily have references to PLM processes and procedures, even when the tasks and jobs are closely linked to the various sub-areas of PLM. In the early maturity phases of PLM the different tasks are not seen as relating to PLM.	Development of personnel and their competences is in a very significant role (in PLM maturity development) Also necessary changes in thinking should be considered (e.g. changing earlier product-centered thinking into more service-oriented thinking might be a big challenge in advancing the PLM maturity steps) In advancing the maturity steps, it is important to communicate to personnel and different functions the ways that present operation changes, what is sought with the changes, and what are the benefits in implementation of changes)
Information Technology	One challenge was the use of PLM concept instead of PDM. Also, a (small) company doing project business does not necessarily need a PDM system as such, so the IT solutions may have a different focus than in the maturity framework. The maturity assessment –related questions and topics could be applied to concern a) manual b) semiautomatic c) automatic IT solutions (concerning the processes of information acquisition and creation, transfer, dissemination, storing, re-use and change management.	Should be taken into consideration in this maturity dimension that commonly there is not only one PLM information system in the types of companies like EngCo2 but several ones (CRM, ERP, PDM): increased information integration in an important role in PLM maturity advancement, ensuring that responsibilities are clarified and there are no contradictory or parallel information in different systems.