The maturity of Product Lifecycle Management in Dutch organizations
A strategic alignment perspective

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technical report UU-CS-2005-009
www.cs.uu.nl

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Abstract

Product Lifecycle Management (PLM) is increasingly important for organizations acting in dynamic and competitive markets. In practice however, companies struggle with adopting and implementing PLM. PLM is rather a concept than a system, as its main premises are to improve competitive advantage through agility and innovation. The concept implies structural, cross-functional and long-term cooperation between actors in- and outside the firm. This complexity hampers the achievement of a solid PLM approach that truly integrates all organizational aspects and levels. The central aim of this paper is to develop a framework that supports such an integrative PLM approach. This framework builds upon insights from business/IT-alignment and capability maturity. It is made suitable to assess organizations that are in different stages of adopting, implementing or evaluating PLM. The results of a first empirical assessment of 23 Dutch organizations are presented. This data set is used to empirically validate the framework and to provide benchmark data. The framework and benchmark data provide a basis for a PLM roadmap towards competitive advantage.

Keywords: product lifecycle management (PLM), strategic alignment, capability maturity, benchmarking, competitive advantage

INTRODUCTION

1.1 The opportunities and threats of PLM in industry

Product Lifecycle Management (PLM) is defined as the activity of managing a company's products across the complete lifecycle, from the early stages of conception to the final disposal or recycling of the product (Stark, 2004). Since the late eighties of the previous century, PLM received explicit attention. Its manifestation started with Computer Integrated Manufacturing (CIM), which evolved into Engineering Data Management (EDM) in the early nineties and later into Product Data Management (PDM). During this evolution the scope shifted from solely the engineering department to the complete product lifecycle and hence the whole supply chain. Moreover, the focus shifted from a pure data management problem to a business problem.

Companies that apply PLM concepts and systems can be found in different industries. Examples are the automotive and transport sector, aerospace and defense, process industry, life sciences, and heavy machinery (Burkett et al., 2002). These industries have unique characteristics and therefore different applications of PLM. In addition, the company's supply chain position (Original Equipment Manufacturer (OEM), Tier 1 or Tier 2 supplier) strongly determines the perception of PLM (Burkett et al., 2002). Despite these differences, companies invest in PLM for clear common business goals.

Important drivers of PLM are the need for shorter product lifecycles, urge for more complex products in terms of components and functionality, trends of globalization and outsourcing and consequently complex supply chains, the need for customization of products due to more demanding customers, and increasing regulations such as safety, environmental and product reliability regulations (McGrath, 1996; Cimdata, 2002; Myer et al., 2002; Ausura and Deck, 2003; Stark, 2004). Companies that are successful in dealing with these PLM related issues report benefits such as increased innovative ability, shorter time-to-market, increased profits, less engineering changes late in the lifecycle, less product faults in the field and higher efficiency (Cimdata, 2002; Stark, 2004).

To reap strategic benefits many companies have started to implement the PLM concept more profoundly (Diepstraten et al., 2002). At the same time we see that companies struggle with adopting and implementing PLM (Wognum and Kerssens-van Drongelen, 2001). A major reason is that PLM affects a wide range of processes within and outside the company. This makes PLM a complex organizational change effort (Sackett and Bryan, 1998; Wognum and Kerssens-van Drongelen, 2001). In practice, the duration of PLM implementations varies from 31 to 45 months (Abramovici, 1999). Also, PLM software implementation itself is complex: it involves not just one system but many systems (i.e., ERP, CAD/CAM, CAE, PDM) that have to be integrated with each other.

1.2 Research question and research methodology outline

Given the potential of PLM, and the current struggle of many companies with regard to its deployment, in this paper we aim to:

> *explore the 'optimal' deployment strategy for companies to accomplish significant added value and hence competitive advantage through PLM.*

We claim that the successful deployment of PLM should encounter two aspects: PLM maturity and Business/IT alignment. PLM maturity refers to the evolutionary and cumulative nature of the deployment process. The organization has to go through different stages of growth before PLM is implemented at all levels and connects all managerial aspects. Business/IT alignment on the other hand, implies that the investment domains related to PLM should be balanced. For instance, the IT-part of PLM should be in line with the business domain and vice versa. In other words, PLM software functions can only be optimally leveraged if the organizational readiness for PLM is mature.

A conceptual 'PLM framework' is constructed, which builds upon insights from business/IT alignment and capability maturity. The framework enables us to assess organizations that are in different stages of adopting, implementing or evaluating PLM. Empirically, it is operationalized by a structured questionnaire that is validated through 23 representatives of Dutch firms in 2004. Based on this empirical research, the framework provides a basis for assessment and hence PLM advice. Moreover, the data set of 23 PLM experiences not only provides generic benchmark opportunities, but also takes company characteristics (such as company size, supply chain position, etc.) into account. Drilling down the values of these background variables facilitates further situational PLM advice for organization towards competitive advantage. We believe that the accumulation of the individual assessment and benchmark analysis contributes to the determination of the critical success factors of PLM implementation.

Our claim with regard to the empirical part might be limited because it is only applied to businesses in the Netherlands. We believe however, that the Dutch situation is comparable to many post-industrial countries. In 2002, CGEY reported that there are over 150 PLM implementations in the Netherlands, which is approximately 6 percent of the total number of PLM implementations in Europe (Diepstraten et al., 2002). From this report it also appeared that

the Dutch PLM implementations are equally distributed over the different industries compared to the rest of Europe.

1.3 Organization of the paper

The next section will describe the construction of our PLM framework and its theoretical foundations. In section 3, the data collection is described that contributes to the empirical validation of the PLM framework. In the first part of section 4, the results of this validation are presented. In the second part the consequences and guidelines for PLM benchmarking are presented. Section 5 closes the paper with conclusions and recommendations for managers and organizations, including suggestions for further research.

2 THEORETICAL FRAMEWORK

2.1 PLM maturity

As both deployment and accomplishment are growth-related parts of our central research question, the first pillar of our theoretical framework is based on the concept of progress maturity. In general, the idea of maturity is presented by sketching a number of growth stages that depict the potential-upward development or performance of organizations during several sequential periods of time. In most representations time or periods are labeled on the horizontal dimension, whereas the performance level is projected on the vertical dimension. Within the field of information systems, the Nolan model is often quoted as the origin of the maturity perspective (Nolan, 1979). Nolan's model represents the specific pattern of IT-adoption or IT-management by organizations. Its baseline is that IT-adoption or IT-management are adopted slowly by a small group at the beginning of its emergence, quickly followed by a large group, and finally with a small group that might stay behind in adoption for a long time. This pattern is labeled the S-curve, as this resembles the cumulative frequency distribution of adoption within groups (cf. Rogers, 1995). With the adaptation of the Nolan growth model by the movement of quality management and related activities, the principle of defining stages of growth was further extended and applied to the development of organizations or their parts. Within the field of information systems planning, Earl's model of learning curves with respect to IT can be considered as one the first examples of this extension (Earl, 1989). Since then, both the original Nolan and Earl models have been revised, extended, specified and modified, in line with progress made in the field of information systems and software engineering (see Galliers, 1991). After publication by the Software Engineering Institute (SEI) at Carnegie Mellon, the Capability Maturity Model (CMM) has become an established model in the field of information systems. It is designed to measure, monitor and evaluate the professional development and engineering of software and many related domains such as IT-governance, project management, people management and so on (Peppard and Ward, 1999), with the assumption that the higher the level, the more mature and the higher the performance of an organization.

In this paper we use the capability maturity concept. Doing so, we deviate from the CMM/IS-tradition in a number of ways. First, we define the stages as (1) doing a particular investment or not, subsequently (2) deploying the investment within the organization following an integrative, cross-departmental route, and (3) finally extending the investment outside the organization, i.e. in cooperation with value chain partners. These are the three basic 'stepping stones' in our application of the maturity concept, which largely draws back on the general literature about extended enterprises (cf. Dyer, 2000), and value networks (cf. Bovet and Martha, 2000).

From these three stepping stones, four maturity levels are defined (cf. Ausura and Deck, 2003):

- No PLM investment, or on 'ad-hoc' basis only (level 0). Nobody is responsible for PLM and there is no vision available for PLM. Therefore, there are no consistent PLM processes and supporting systems. At this level, information about a product is scattered throughout the organization, which hinders strategic decision-making.
- On departmental level ('silo' orientation) (level 1). PLM is seen as a data management problem that should be dealt with on departmental level, but there is no overall vision to coordinate local initiatives. Often the development or engineering department is the first department that starts to implement PLM systems. At this level, at least all information regarding the early stages of a product is stored in a central system.
- On the organizational level (cross-departments) (level 2). PLM is interpreted as a business problem that requires a corporate vision and an integral approach. Besides engineering and development also other departments are heavily involved. PLM processes are defined that cross departmental borders and company wide PLM systems are implemented to support these processes. Moreover, PLM systems are integrated with other major enterprise systems, such as ERP. At this level, all product information within the company is stored in a central system and there is control information available regarding PLM processes.
- On the inter-organizational level (cross supply chain partners) (level 3). PLM is seen as a business problem that spans the complete product lifecycle. Therefore, the supply chain should be involved in defining a PLM vision. PLM processes are defined that cross organizational borders and PLM systems are integrated with those of the suppliers to enable collaboration. At this level, all product information across the product lifecycle is stored in a central system making the product lifecycle become transparent enabling proper decision-making concerning a product.

2.2 PLM alignment

The second pillar of our framework is based on the concept of business/IT-alignment. Since the 1980's, scholars, analysts and consultants alike have advocated an aligned approach with regard to introduction and deployment of information systems (IT) in organizations. One widely cited source is Porter (2001), who argues that the Internet does not make business strategy obsolete. Instead, an Internet and business strategy should coincide. On an operational level, many authors can be cited for the statement that IT implementations should come along with a careful consideration of business processes and other organizational issues (cf. Peppard and Ward, 1999; Hammer and Champy, 1994). This message is also recognized within practical guidelines, such as Sowa and Zachman (1992) who propose a system development perspective that can be considered holistic, taking the views of data, function, network, organization, strategy, and scheduling into account. All of the mentioned authors similarly encourage the alignment of IT with business processes, structures and strategies.

Historically, Scott Morton's book on *The Corporation of the 1990's* (1991) can be considered as the foundation of business/IT-alignment. Better known however, is Henderson and Venkatraman's Strategic Alignment Model, one of the first concepts to support organizations in leveraging new IT technologies (Henderson and Venkatraman, 1993). Business strategy, IT strategy, organizational infrastructure and processes, and IT infrastructure and processes should be in balance through strategic fit, and functional integration (see also Luftman et al., 1993). Subsequently, several authors applied the Strategic Alignment Model. With varying success, the connection between alignment and organizational performance has been investigated (Cragg, et al., 2002; Kearns and Lederer, 2000; Peppard and Ward, 1999).

If we apply the Strategic Alignment Model to the field of PLM, the business domain of the model clearly needs to be extended. As we argued before, PLM is connected to many management domains that cannot be aggregated to one area, either on the strategic nor operational level. One

way to elaborate the business domain (while explicitly connecting it with the IT domain) is by using the model of Turban, et al. (1999) and specifically its extension by Scheper (2002). In Scheper's adaptation of the model, the following five 'business dimensions' are crucial parts of every organization that need to be integrated:

- Strategy and policy
- Monitoring and control
- Organization and processes
- People and culture
- Information technology

In his concept of alignment Scheper stresses that not only maturity levels for each of the five dimensions are important, but also their balance and interconnection. In his empirical framework, four maturity levels are labeled for each dimension: 'ad hoc', 'process orientation', 'system orientation', and 'network orientation'. Basically, his hypothesis is that synchronizing or leveling of the five dimensions will significantly contribute to the performance of an organization. Based on data collected from 265 Dutch housing corporations this hypothesis is indeed confirmed (Scheper, 2002). In addition, the same hypothesis was confirmed by data collected among 30 CRM-managers (Batenburg and Versendaal, 2004).

In our framework we will follow Scheper's framework of (strategic) business/IT alignment. In fact, its foundations are applied to combine the concept of PLM maturity and PLM alignment within one integrative framework. The four maturity stages as defined in the previous section are allocated as the concrete achievement levels for a (equal) number of indicators that cover each of the five business dimensions in relation to PLM. The empirical appearance of the framework will be described in the next section. At this point, it is important to stress that our PLM framework serves the goal of measuring, monitoring, and comparing corporate PLM activities through self-assessment in absolute and relative terms. The key is that (1) this framework is theoretically instead of commercially driven, and (2) it is generally applicable, but it provides situational instead of general recommendations.

2.3 Related work

The concepts of alignment and maturity are not new and have been identified by other scholars and practitioners. A well-known example is the Balanced Score Card (BSC) by Kaplan and Norton (1996) in which companies can be evaluated and assessed using four dimensions: finance, organization & processes, customer-orientation, and the learning organization. Another example is that of Kim et al. (2003) who created a framework for assessing the effectiveness of Customer Relationship Management (CRM) by developing a specific instance of the BSC. Clearly in line with this paper, Batenburg and Versendaal (2004) have presented an integrative and testable framework for assessing companies in the CRM domain (Batenburg and Versendaal, 2004).

Related work in the field of PLM is research that addresses Product Data Management (PDM) implementations, a critical information system that enables PLM. For instance, Abromovici (1999) conducted an international study under 100 executives of 33 different companies. Amongst other things, he reports that for 'Champion companies' it takes on average 31 months to implement PDM, while at 'Followers' it takes on average 45 months. In a case study, Helms (2002) also reported about lengthy PDM-implementations in the order of several years. Moreover, Wognum and Kerssens-van Drongelen (2001) have conducted a survey under Dutch manufacturing industries about the current status and problems with PDM-implementations. The findings have resulted in a first step toward formulating guidelines for implementing PDM. Finally, consultants like Stark (2004) made a first attempt to define several maturity stages for Product Data Management (PDM).

The previous overview demonstrates the gap in scientific research on PLM and especially the success and fail factors of PLM deployment in its broadest sense. Obviously, because of its upcoming nature the drivers of PLM performance are still hard to detect empirically. This research, based on data from 23 organizations that are in different stages of PLM deployment, includes several additional values to this related work. First of all, the novelty can be recalled of an integrative framework that models the PLM concept. Secondly, it should be noted that the underlying assumptions of many related maturity or alignment models are rarely tested on their validity and robustness. Finally, our PLM framework is used as a guideline for detailed assessment by taking into account background characteristics to perform 'situational benchmarking'. This is based on the idea that competitive advantage on each of the dimensions (maturity ladders) of the PLM framework can be specified according to common characteristics such as sector and company size. It enables us to explore what might be a 'best' strategy for the optimal leverage of PLM.

3 DATA COLLECTION

To validate and apply our PLM framework, a computer-aided questionnaire was constructed. Its core contains an assessment of all the issues from the framework. In addition, the questionnaire contains questions about company details and performance indicators. The first version of the questionnaire was pre-tested by three PLM customers of one of the world's largest extended ERP vendors in October 2004. Each of these customers was asked to complete the questionnaires, providing answers to the questions using 'thinking aloud' techniques (cf. Nielsen, 1993) through conference calls. The feedback from these pre-tests were used to improve the questionnaires on aspects of validity (does the questionnaire properly measure all issues from the PLM framework?), reliability (is each question posed correctly?), and practical application (has the questionnaire the right size?).

In October and November 2004, 23 managers from an equal number of Dutch firms were invited to participate in three different group discussion meetings about PLM. The managers were recruited using the personal and professional networks of scholars and master students Business Informatics at Utrecht University. This resulted in what is called a 'convenience random sample' (Triola, 2004). All managers made a personal commitment to enter the discussion meeting and to seriously add value to this academic initiative. Table 1 summarizes the participants' organizations, by industry and size.

Type of industry, product or services	Medium size (15-1,000 employees)	Large size (Over 1,000 employees)
Equipment and transport companies	3	5
ICT solution providers	1	5
Product software companies	6	1
Financial services	1	1
Total	11	12

Table 1. Basic characteristics of the participants' organizations

Our sample of 23 respondents from a similar number of organizations is almost equally divided if we handle 1,000 employees as a (common) boundary for company size. Classifying the respondents according to their type of industry results into a somewhat peculiar categorization. ICT and software companies are over-represented compared to the industries that are usually researched with respect to product lifecycle management and related issues. IT organizations however, are of increasing importance to modern industries, and typically design, construct and

engineer products, i.e. product software and related services (Cusumano, 2004). In addition, this sector is particularly known for its fast moving technology and customer preferences that put strong pressure on their products lifecycles and, hence, PLM. There are only two financial service companies that develop and produce services as 'intangible products'.

All respondents were asked to complete a questionnaire to assess their organization according to the PLM framework. The questionnaire consisted of 40 questions, 8 for each of the five business dimensions (strategy & policy, organization & processes, monitoring & control, people & culture and information technology). The pre-structured answer categories for each question reflect the (partial) maturity of the company on the four-point scale as presented earlier. Every question consisted of two parts, the first part asking if the PLM issue was arranged or taken care of in the organization at all, the second part was applicable if the first answer was 'yes' and contained the four maturity levels. Taken together, every question was coded as 0 ('no'), 1 ('ad-hoc'), 2 ('departmental'), 3 ('organizational'), or 4 ('inter-organizational'). The questions within each business dimension cover what we believe are important PLM specific issues, related to the particular domain. These are summed below in Table 2.

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

Table 2. PLM issues (items) in the questionnaire by business dimension

In addition, some general questions about the characteristics of the company such as position in the value chain, company size, industry, were posed. The complete questionnaire is available upon request from the authors.

In practice, the participants completed the questionnaire independently using the Survey-tool within GroupSystems, a widely used software tool for supporting group discussions and meetings (cf. Weatherhall and Nunamaker, 1999). From every meeting it appeared that all items were recognizable, understandable and suitable to answer. This can be considered as the positive result of the extensive pilot of the questions with three different PLM customers of a major ERP vendor. Given the fact that managers in the group sessions represented a large variety of organizations, it was satisfactory to notice that most participants experienced the questionnaire as a complete and structured checklist for PLM. This provides us with confidence about the quality of the particular measurement of PLM activities and the PLM framework itself.

4 RESULTS AND ANALYSIS

4.1 Outcomes of the PLM framework

Our first step is to validate the PLM framework by the data that were collected via the electronic questionnaire during the group meetings. An important assumption to be tested concerns the resemblance of the eight questions (items) per dimension of the framework. Although the questions touch upon different aspects of PLM, they are expected to correlate positively as indicators of maturity on the particular business field. Specifically, all items are judged by the respondents on their level of governance, varying from not (coded as 0) to inter-organizational (coded as 4). Since the measurement levels and nature of the variables are similar, scale analysis is an appropriate tool of analysis to test for consistency within the five sets of eight items. From reliability analysis (alpha model) in SPSS, it appears that all the 8-item sets indeed resemble to internally reliable scales. Chronbach's alpha for the strategy & policy-items is .89, for organization & processes .86, for monitoring & control .76, for people & culture .74 and for information technology .87. To conclude, all questions are relevant to be included into the dimensions of the framework. By calculating the weighted sum of the eight items, one final score per dimension is achieved. Subsequently, these aggregated variables enable us to visualize both the average PLM maturity and alignment using a radar plot (Figure 1).

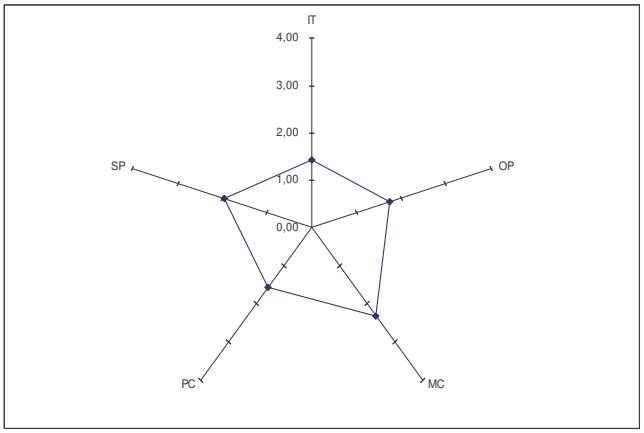


Figure 1. Collective results of the PLM assessment in the framework (N=23 Dutch organizations)

From figure 1 it can be seen that the participating companies hold scores between one and two and a half on all five dimensions. This indicates that all the issues as presented in the

questionnaire (see Table 2) are generally encountered at least on the individual level within the organization. The PLM items that are related to IT, and to people & culture have a relatively low maturity score, whereas issues regarding monitoring & control and strategy & policy are dealt with on a higher (departmental or organizational) level. At first sight, this result supports the general idea that PLM is initiated from a strategic level (top-down), and is priory deployed to upgrade management control and process management with regard to the product lifecycle. In particular, the high scores on (PLM) monitoring and control seem to resemble much of what was known as total quality management in earlier decades. IT and the 'human factor' might be involved in a later stage for many organizations, being the supportive or perhaps more complex dimensions to govern in relation to PLM. Consequently, this result indicates that companies can attain competitive advantage by investing in these business domains.

4.2 Benchmarking using the PLM framework

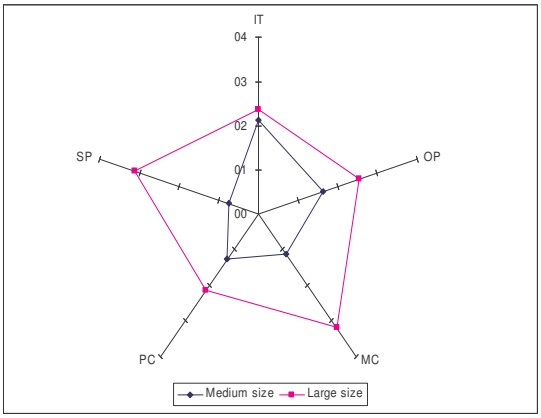
Figure 1 shows the average PLM maturity and alignment of the 23 companies in our data set. Obviously, it appeared there is variation in both maturity and alignment. Some organizations only cover the 'inner space' of the picture, not exceeding the mean of 1.0 on each dimension of the radar plot. Other companies approach the maximum scores on some dimensions (but mostly not on all five). For the sake of straightforward interpretation we define:

- PLM maturity as the overall mean score on the five dimensions (the higher, the more mature). The mean of this constructed variable is 1.79, its standard deviation 0.77.
- PLM alignment as the standard deviation of the same array of five dimensional scores (the lower, the more aligned. The mean of this constructed variable is 0.61, its standard deviation 0.31).

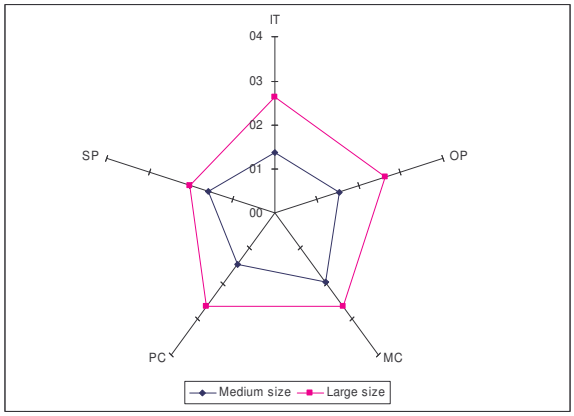
Remarkably, these two variables do not correlate significantly with each other ($r = .08$, $p = 0.72$). This implies that achieving high maturity on the dimensions does not coincide with a well-balanced alignment score in this respect, and vice versa.

This variation and co-variation in our data set can be used for benchmarking organizations in several ways. First, the company with the highest maturity and alignment might serve as the 'best practice' within the limited scope of our survey. It appears that 'a global player in the IT solution sector', and 'a multinational business unit in imaging equipment' (names cannot be provided due to anonymity agreements) have the highest maturity *and* alignment score. Of course, this result can trigger all types of ideas or inspiration for other organizations although we would advocate being careful in this type of generalization. As Peters and Waterman claim in the latest edition of their famous *In Search of Excellence* (the study that became widely known for its construction of the 7-S model through inductively studying the characteristics of the best performing organizations during the eighties in the US), benchmarking is a very relative activity according to both time and location (Peters and Waterman, 2004). So the second type of benchmarking that might be of more relevance recognizes the relevant characteristics of companies, in particular size and sector. In line with the six size/sector-combinations in Table 1 above, the 'local' scores maturity and alignment are presented in figure 2.

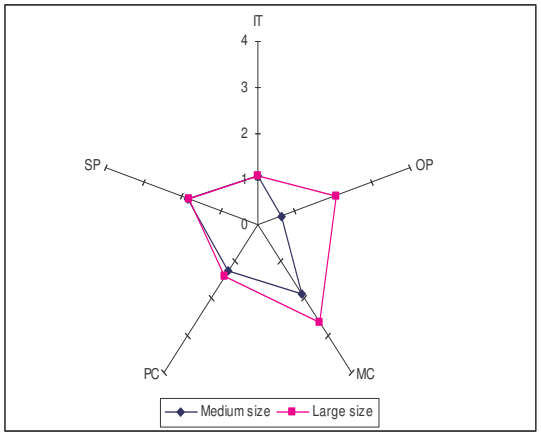
Taken the small numbers of observations into account, the four categories show considerable differences in Figure 2. The product software companies and the large software companies show well aligned radar plots, whereas the equipment and transport, as well as the financial services clearly stay behind on the IT-dimension. The small product software and ICT solution companies lack maturity on strategy & policy. In general, the 'medium' companies show lower scores on most dimensions compared to the relatively larger companies.



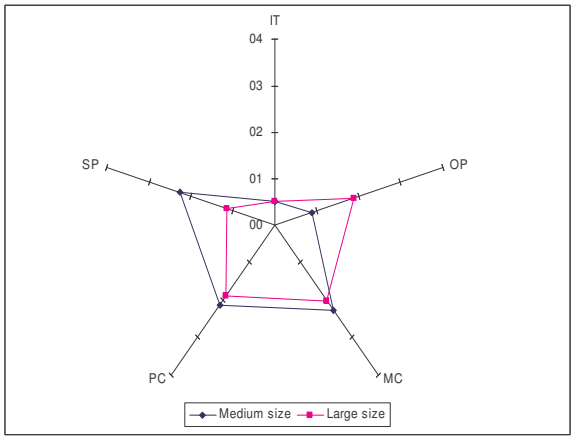
ICT solution providers



Product software companies



Equipment and transport



Financial services

Figure 2. Results of the PLM assessment by industry and by size

5 CONCLUSIONS AND RECOMMENDATIONS

PLM is a relatively new concept that is – so far – hardly addressed in scientific literature. Software vendors, business analysts, and software evaluators dominate the publications about PLM. With this paper, we believe that we have contributed to the theoretical and empirical analysis of PLM and, based on this, provided a practical framework for organizations that are deploying PLM or aiming to start with this trajectory.

Using the concepts of strategic business/IT-alignment and capability maturity we developed a PLM framework that was used to assess the PLM activities of 23 Dutch firms. Respondents from these firms completed a questionnaire during a group discussion meeting, assessing their company on 40 different PLM issues divided over five elementary business dimensions (strategy & policy, organization & processes, monitoring & control, people & culture, information technology). Maturity levels of each PLM issue varied between 'not considered' and 'taken care on the inter-organizational level'.

From our sample of Dutch 23 respondents, it can be indicated that generally information technology and people & culture are the business domains organizations relatively stay behind in PLM maturity. Issues like inclusion of PLM in job descriptions, the involvement of employees

with the implementation of PLM software, the integration of PLM software are merely not organized or on an ad-hoc basis only. Issues with regard to PLM strategy description, product quality monitoring through PLM and formal description of PLM procedures are dealt with on the departmental/organizational level. In other words, PLM issues with regard to policy & strategy, organization & processes and monitoring & control are organized on a somewhat more mature level compared to people & culture and information technology. On average, the highest inter-organizational level is far away for most organizations, although some of the (larger) IT companies in our sample are well on their way.

These results imply that much progress can be made on each of the five dimensions, while differences between sectors and size group of companies should be taken into account. Obviously, the low maturity scores on people & culture stress the often advocated importance of the 'human factor' in technical-originated concepts like PLM. In addition, organizations can obtain competitive advantage by investing in IT (i.e. PLM software), since many (non-IT) organizations in our sample are lagging behind on this particular domains. All these suggestions should be accompanied by the notion that achieving a high maturity on the dimensions does not resemble with a well-balanced score as we found in our empirical analysis. Hence, PLM investments should be conducted having a integrative plan that assures the concept of alignment. Such a structured approach can be called a 'PLM roadmap'. This roadmap should describe and monitor the actions or projects to bring a company to the next level of PLM maturity *and* alignment. We suggest the following approach to support the development of a PLM roadmap that is based on the PLM framework presented in this paper:

1. Determine the as-is maturity and alignment level of your company using the multi-dimensional PLM framework and corresponding questionnaire. Preferably, complete the questionnaire with a small group of responsible managers and compare the results to check on consistency.
2. Benchmark your company's as-is maturity level against the best-practices in your industry using the benchmark data presented in this paper. Highlight the low-maturity dimensions (like people & culture) through comparing the absolute and relative scores for your organizations
3. Based on the benchmark results, determine the desired maturity level of your company. Given the nature of the maturity concept, note that it is too ambitious to increase more than one maturity level at the time. In addition, make use of the *portfolio* of PLM issues that are important within each business domain as outlined in Table 2 of this paper. Goal formulation should be drilled down on the level of the concrete PLM issues of our framework/questionnaire.
4. Define a PLM roadmap in order to integrate and mutually adjust the investments towards the desired PLM maturity defined in each domain. During the execution of the projects, monitor the level of alignment between the business domains. The concept of program management (which in itself is a part of PLM) might be of use to achieve balance and integration.

Since we are at the starting point of a new research area, there are many areas for future research. Obviously, for improved validation of the PLM framework many more organizations need to be assessed. More data will improve the benchmarking opportunities, especially if company characteristics are carefully taken into account. Furthermore, we believe the questionnaire can be further improved if more data support the interpretation of scale analysis and variable construction. In particular, it might be an important step forward if structural weights can be allocated to the different items as an indication of their importance to their business dimension, and to the overall alignment. Finally, we believe that a likewise maturity/alignment framework

can be applied to other areas than PLM, as exemplified in the CRM area (Batenburg and Versendaal, 2003), and in domains like procurement, logistics and finance.

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