Challenging Requirements Management Issues in PLM Implementation - Findings from a Retrospective Case Study.

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Abstract: In this paper, a recently conducted PDM implementation project in the manufacturing industry is analysed. The aim is to clarify the role and impact of requirements management methods and processes in PLM implementation projects. A literature review summarises existing PLM implementation models. This is followed by an in-depth examination of how a real PDM implementation project was conducted, mapping out the rationale for different courses of actions and the effects they have resulted in. The most challenging requirements management issues in the PDM implementation project are identified and discussed. It is demonstrated that requirements management activities need to form a coherent whole from scoping to testing to contribute to a successful project outcome.

Keywords: PLM implementation, Empirical study, Implementation model, and Requirements management.

1 Introduction

1.1 PDM system implementation – motives and challenges

Product Data Management (PDM) systems must be continuously upgraded over time. Minor changes to PDM processes can usually be realised through different add-ons and customisations to the existing system. However, the gap between the desired processes and the support available from the existing system eventually becomes too large, leading to a need for systems replacement. When using a commercial PDM system for the implementation a gap always exists between the desired processes and the available support from the system. Therefore, two main strategies exist in PDM implementation: customise the commercial system to fit the desired processer, or change the desired processes to fit with existing support in the commercial system (Saaksvouri and Immonen, 2005).

Product Lifecycle Management (PLM) implementation projects are complex. Grönvall (2009) compares PLM implementation with heart transplantation and states that PLM implementations carry many dependencies and uncertainties and therefore are high-risk projects. Several authors (e.g. Saaksvouri and Immonen, ibid) stress the importance of a thorough analysis of business processes and requirements before implementing a

PLM system and while the purely technical part in itself might be a challenge, the organisational part is even harder (Garetti et al, 2005).

The economic benefits of more efficient PLM solutions and PLM implementation are well-known. However, other benefits may be highlighted as well. More efficient PLM solutions may reduce the environmental load occurring in the development process, e.g., in less CO2 emissions from travel to meetings and less material consumed to produce physical prototypes. Moreover, like other major organisational changes, PLM implementation adds to the already existing pressure in organisations. Smoother transitions from current state to future state minimize the extra pressure and thereby contribute to a healthier work environment.

1.2 PLM implementation support

Several theoretical process models for PLM implementation have been proposed (for example, Schuh et al, 2007; Bitzer et al, 2008; Batenburg et al, 2006; Kumar and Midha, 2006). They focus on requirements management support for early phases of a PLM project, resulting in a system being selected, but provide less detailed instructions for subsequent tasks (how to customise the system, for example).

Other authors compare the use of different implementation processes (e.g., Morandotti, 2007; Wognum and Kerssens-van Drongelen, 2005). Eynard et al (2004, 2006; see also Merlo et al, 2005) suggest a specification-driven, object-oriented approach to describe requirements on a PDM system. Wognum and Kerssens-van Drongelen (2005) suggest an evolutionary approach, as the focus in PLM implementations tends to change. The recommendations thus differ; no dominant PLM implementation reference process has yet emerged.

Some works based on empirical case studies have also been presented (examples include Pikosz et al, 1997; Rangan et al, 2005; Wognum and Kerssens-van Drongelen, 2005; Zimmerman, 2008). They formulate guidelines for what to do when implementing PLM, both regarding requirements management and organisation change management. They state what needs to be accomplished, but provide less guidance on how to carry out the task (for example, *how* to minimise customisation). In addition, where cases are referred to, the implementations in such are only briefly described (with the exception of in Zimmerman, 2008). As a result, readers of those articles may find it difficult to apply the guidelines in practice, and to understand what the consequences can be if they are not applied.

We conclude that there is a lack of research that focuses on the operational level of PLM implementation, specifically regarding requirements management and PDM system customisation. Systematic studies of real implementation efforts are essential in order to bring out this knowledge.

1.3 Research aim and approach

The aim of this paper is to clarify the role and impact of requirements management in PLM implementation. Furthermore, the paper aims to identify and discuss challenging PLM implementation issues. This is done through an in-depth study of a recent PDM implementation project in the manufacturing industry.

1.4 Paper outline

The remainder of the paper is structured in the following way. Section 2 first outlines the research approach taken in the study. A thorough description of the project studied is presented in Section 3, followed by a discussion of the most challenging requirements management issues in Section 4. We then discuss the research approach and validity of the results in Section 5. Finally, we present our conclusions in Section 6.

2 Research approach

PLM implementation projects are complex and multi-dimensional. Project organisation, process, methods, and changes in the global economy are only some of the aspects that affect project outcome. Therefore, a qualitative systems approach has been used in the research. This calls for an in-depth case study (Yin, 2003), with multiple data sources such as interviews, documents, reference group meetings with company employees and seminars, in order to understand the underlying factors for courses of actions and to minimise bias.

The project studied was conducted during 2006-2009 at a multi-national company in the manufacturing industry (hereafter called GlobalGroup). GlobalGroup delivers commercial solutions in various areas and is divided into multiple divisions, some of which were involved with the studied project.

GlobalGroup used (and still use) several PDM systems with different functionality. Some are developed in-house while others are based on commercial off-the-shelf (COTS) systems from different vendors. Earlier, they had gone through a larger PLM initiative (cf. Zimmerman, 2008) that resulted in a decision to phase a PDM system from one of their vendors (hereafter called VendorCorp). GlobalGroup decreased the maintenance budget for the system, but it continued to work well and was not shut down. However, in the summer of 2006, VendorCorp announced that their system support would end in two years' time. Unwilling to take the risk of using a system not supported by the vendor, GlobalGroup decided to replace it, together with some other systems connected to it.

The case is a suitable object for study for three main reasons. First, the project has been performed in a multi-national environment in a company with multiple sites and company divisions around the world. Also, the two systems (before and after) were significantly different. The architecture and user interfaces of the systems differ, and the new system enables a much more comprehensive PLM support. The case therefore allows for insights into a wide range of PLM implementation issues. Second, the company studied has performed several PLM implementation projects prior to the actual case. Therefore, it represents current practice within the field, without having to regard "beginner" issues. Third, the project recently ended, during the fall of 2009. Therefore, the findings reflect current PLM practice.

Seventeen semi-structured interviews (with 21 interviewees) were performed during the case study. The interviewees were sampled according to a heterogeneous strategy in order to represent as many viewpoints as possible. All interviews lasted for two hours each and were done by at least two interviewers, and were recorded, transcribed and sent to the interviewees for validation.

In addition, more than 200 project and company documents were analysed. Examples of those documents include white books, meeting minutes, communication letters and technical documentation.

As part of the data structuring, interview statements were cut out and grouped into five main areas, as presented in Section 4. Communication letters and meeting protocols were summarised in a few sentences and added to the analysis, and the technical project documentation was analysed in depth.

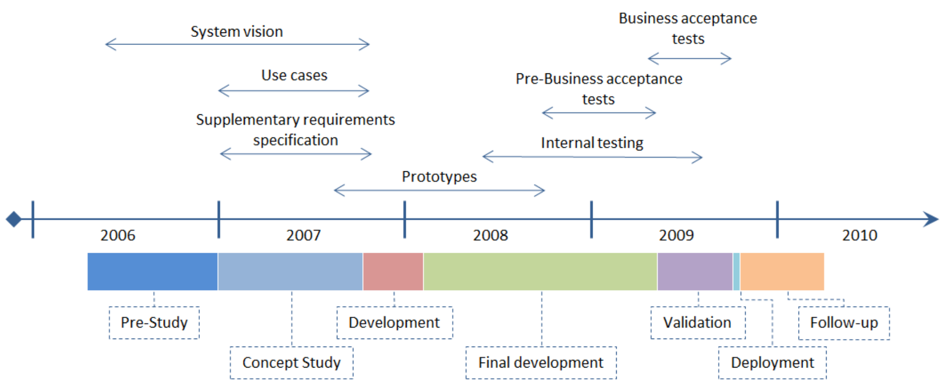
For validation, preliminary findings have on three occasions throughout the study been presented for a reference group, which consisted of managers from the IT department and other departments. A presentation with final findings was held for the reference group and most of the participating interviewees. In addition, two presentations were held at another company, with characteristics similar to GlobalGroup. All of these groups corroborated the validity of the findings.

3 Project description

3.1 Implementation process

The project followed GlobalGroup's global project model for the development of information systems. It is a waterfall stage-gate model with seven phases (pre-study, concept study, development, final development, validation, deployment and follow-up) (See Figure 1). In this section, a chain of events through the different phases is presented.

Figure 1 GlobalGroup's project model for the development of information systems, with requirements engineering activities highlighted



3.1.1 Pre-Study phase [October 2006 – January 2007]

A pre-study team, led by the business divisions with input from the ITDivision, concluded that the most suitable solution would be to replace the existing system with a new COTS system from VendorCorp, despite GlobalGroup's strategy to phase out the use of VendorCorp's CAD and PDM systems. To minimise time and cost, processes were to remain the same. The project aimed at a "1:1 replacement" of the existing PDM system with a particular release of VendorCorp's new generation PDM system. The ratio 1:1 meant that all current *processes* should be supported by the new system. However, many stakeholders interpreted 1:1 as having the exact same *functionality* in the new system as in the existing one. GlobalGroup planned to launch the new system during the fall of 2008, and VendorCorp agreed to prolong the support of the existing system until the new one had been launched.

The project had difficulties getting commitment from all necessary divisions. However, it was ultimately given the go-ahead, and a project organisation was set up.

3.1.2 Concept study phase [January 2007 – November 2007]

In beginning of the concept study phase, it became evident that preliminary cost estimations were too low. Several estimations had previously been too optimistic, and a budget for some necessary areas was missing. New calculations performed by the ITDivision pointed to twice the first estimated amount.

The ITDivision elicited requirements and validated those with the business reference group. System vision, use cases (functional requirements) and supplementary requirements specification (non-functional requirements) were constructed. However, the business reference group had difficulties agreeing on the requirements. All divisions used the existing system in different ways, and it was unclear what functionality could be customised in the new system for each division and what functionality had to be common. In order to understand the system possibilities and constraints, the business reference group members took a training course in the new PDM system, the off-the-shelf version.

A project audit, led by GlobalGroup representatives, concluded that the various business divisions had to unite their visions and agree upon requirements. It was also suggested that concept prototypes should be constructed in order to identify critical areas where the COTS solution would not be enough.

The ITDivision constructed the concept prototypes (essentially solution mock-ups in presentation slide format) and presented them to the business reference group. Based upon the concept prototypes, it became evident that the out-of-the-box release initially aimed at would require major customisations to meet the GlobalGroup's needs. The project sent a system change request with additional functionality to VendorCorp, who agreed to include the new functionality in their next release. The project decided to implement the new release instead of the existing one and the consequence was a time delay.

A new large PLM strategy initiative had started and was now running in parallel with the implementation project. VendorCorp was once more evaluated and compared with its competitors by GlobalGroup. This evaluation further delayed the implementation project. However, in late 2007, it was concluded that VendorCorp was one of the two remaining competitors going through a final evaluation. Commitment from business reference group members in the implementation project increased substantially. Shortly after the notice, the project continued to the next phase, bringing with it almost finished use cases, supplementary requirements specifications and concept prototypes.

3.1.3 Development phase [November 2007 – January 2008]

However, work had continued while waiting for the result from the new PLM strategy initiative. Therefore, the development phase was short, lasting from November 2007 to January 2008. Use cases, the supplementary requirements specifications and concept prototypes were finished and approved. It was now assessed that the largest project risk would be a delay in the new product release from VendorCorp, who had promised to deliver the new system release in July 2008.

3.1.4 Final development phase [January 2008 – May 2009]

At the beginning of the final development phase, VendorCorp announced that the targeted system release would be delayed. It was not delivered until November 2008 and the quality of the release was assessed as being insufficient for roll out. So the project had to wait for a maintenance release delivered in February 2009.

During 2008, the IT project continued to customise the system at the same pace. The idea was to develop towards the available system environment and upgrade to the new release later. However, this strategy failed, as several previously performed activities had to be done again when the GlobalGroup received the new release. This led to increased costs. At the end of June 2008, about two thirds of the yearly budget had been spent and delivery was behind schedule. The IT project manager was replaced, and the project was re-organised and re-planned.

The IT project tested the solution in two ways, by internal testing and by business acceptance tests. Test scenarios were based (but modified) on the concept prototypes. Several runs of tests were performed from the fall of 2008 to the spring of 2009 that revealed important issues with the solutions, both regarding functionality and performance. New requirements were identified, some changed and some could not be agreed upon. Performance was slower than what was expected by the users, especially for large assemblies. The date for system deployment was postponed several times, mostly because the project had difficulties progressing. In addition, a business division announced that deployment for them would not be possible at a particular time, due to heavy product releases for one of their departments. The steering committee requested that the business reference group accept workarounds and changes that the IT project suggested, so that the project could move on. Finally, the system deployment date was set for August 2009.

3.1.5 Validation, Deployment, Follow-up phases [May 2009 – April 2010]

The validation phase started in May 2009. The final business acceptance tests were performed, and, after the summer vacation, users were scheduled for system education. After a final migration rehearsal, the project progressed to the deployment phase and replaced the systems in September 2009, about a year later than initially planned. There were some technical problems, but none of critical character. A so-called super-support team was established, aimed at supporting the users with knowledge of how and why tasks needed to be performed in a certain way in order to work. The deployment phase ended in October 2009, and the responsibility for the system was transferred to the maintenance department. In the follow-up phase, learning lessons documents were compiled by the business project, the IT project and the system vendor.

3.2 Project results

In summarizing the project, some gains can be identified. While replacing the old system, several other systems became unnecessary and were removed as well. This has led to a less complex system architecture with a decreased number of systems. Also, divisions and even departments therein used the existing system in their own ways, with different methodologies. GlobalGroup now has a globally standardised way of working, e.g. with release management, that has been enabled (and enforced) by the new PDM system.

However, the initial budget was overrun by a factor of three. A too optimistic initial budget assessment is part of the explanation. But a string of events caused additional delays and thus cost overruns: aiming for the wrong system release, poor quality of the initial version of the target release, delays in internal development, and delays due the fact that that product release was prioritised.

Regarding quality, benefits were gained on the divisional collaboration level through more efficient information sharing. However, end-users indicated a decrease in individual user efficiency. One example of this was functionality that required more and non-intuitive mouse-clicks. In addition, the project consciously disabled a specific system functionality, which led to decreased user efficiency. User satisfaction also varied between geographical sites. In addition, poor organisational change management, e.g. communication about the change, lack of education and user support when the system was replaced, probably reinforced the perception of a decrease in user efficiency in the new system.

Overall, several of the interviewees categorised the PLM implementation project as neither a success nor a failure. It was perceived as a normal outcome at GlobalGroup. They managed to replace their PDM system, but the project was both unnecessarily long and costly.

4 Challenging requirements management issues in PLM implementation

Let us now discuss in more detail some identified challenging requirements management issues in PLM implementation projects, namely project scope and goals, implementation processes, requirements elicitation and validation, system testing and user involvement.

4.1 Project scope and goals

Using a system not supported by the vendor would have been a huge business risk. Therefore, GlobalGroup initiated a project to replace its existing system. Hence, the main project objective can be said to have been minimizing risk. Other objectives were to perform the replacement rather quickly and minimise the cost of the implementation.

The project had difficulties in the beginning to get commitment from all necessary divisions, due to GlobalGroup's earlier strategy of phasing out systems from VendorCorp. Even though the project received a budget and was started, it soon became evident that initial preliminary cost estimations had been too optimistic and some necessary areas were even missing. It was not until the results from GlobalGroup's new PLM initiative was announced that commitment increased, almost a year into the project.

The resulting strategy was to perform a “1:1 replacement”, meaning that the new system should provide the same support as the existing one, no less and no more. The aim was to use the existing functionality in the new system, with minimised customisations, an out-of-the-box solution. However, a basic problem with the 1:1 replacement and out-of-the-box strategies was that they were contradictory.

PLM implementation requires knowledge of the business processes (e.g., Saaksvouri and Immonen, 2005). Since the project would be a 1:1 replacement, the business divisions thought there was no need for them to get involved in the project. They argued that the ITDivision already knew how the old system was being used. However, due to the earlier strategy to phase out systems from VendorCorp, maintenance of the existing system had been decreased over a period of several years, and this had resulted in insufficient documentation of the existing system. Therefore, documentation of how the existing system and the process worked had to be created as a part of the project. This led to additional project costs that were not previously anticipated.

Another reason why it was difficult to get business commitment for the project was that the 1:1 replacement strategy was perceived as not providing any benefits. Some interviewees said there were business benefits on a global collaboration layer, but that there were no benefits for an individual user. It was also unclear what a 1:1 replacement meant. Some interviewees interpreted it as the same process support, but with different methods. Others interpreted it as the same functionality and user interface.

Once involved, all divisions aimed to solve their own needs. They were also either unwilling to adapt to, or unaware of how their needs contradicted with, the other divisions' needs. The requirements became harmonised after the project audit, performed during the concept study phase, had highlighted the issue.

In summary, the project scope and goals caused several problems. However, as one interviewee stated it, without the 1:1 replacement strategy that expressed intent to minimise scope and costs, the project might not have received funding at all.

4.2 Implementation process

GlobalGroup's project model (a waterfall stage-gate model) is rather comprehensive, and common views among interviewees were that they "went by the book". Despite this, there were multiple time delays, caused by aiming for the wrong system release, poor quality of the initial version of the target release, delays in internal development, and delays due to the fact that that product release was prioritised. Although a project model should support the assessment and mitigation of external factors, it was unclear how it would deal with these. It seems that would require skills beyond general project management skills and models.

The choice of project model is not self-evident for a PLM implementation project. A waterfall model requires that the complete project scope be completed before the whole project moves to the next phase. Specifying the complete development gap might take a long time. When the specification is complete and the project can move to the next phase, it might already have changed. It is not certain that a complete set of requirements can be described before developing the solution. Wognum and Kerssens-van Drongelen (2005) suggest that a "learning, evolutionary or cyclic approach" should be used for PLM implementation, as the focus in these kinds of projects tends to change. With an evolutionary approach (Sommerville, 2007) the system is more likely to meet the stakeholders' needs and the requirements specification is allowed to develop continuously throughout the project. However, an evolutionary approach is less visible to management, and the system structure is more likely going to be difficult to maintain. Sommerville (ibid) also states that a waterfall process should only be used when requirements are well-understood and unlikely to change often. However, a waterfall process is rather inflexible regarding phases and commitment is needed early, making it difficult to change the scope. Neither of these basic approaches therefore seems to fit fully with the characteristics of PLM implementation projects, which are essentially COTS projects.

Regardless of how the project models look, they prescribe only what should be accomplished at each stage of the project. They do not prescribe how it should be accomplished. On its own initiative, the IT project applied methodology from the iterative work model Scrum. However, this was a first attempt, and integration with the higher-level project model was lacking.

In summary, there was no consensus in the project as to what the best implementation process approach was. Different viewpoints on the implementation process were stated by business and IT, as well as between managements' project models and operative work models. Although different models support the project on different levels, they also affect to what degree collaboration can be achieved between the project actors. An effective PLM implementation process model needs to be two-levelled: a project control level and a work (coding) level.

4.3 Requirements elicitation & validation

When specifying requirements for a COTS system, existing processes and systems must be reviewed and changes to the desired processes and systems must be agreed on. Also, the new COTS system must be reviewed with regard to its possibilities and constraints. The difference between the desired new processes and system and the possibilities and constraints with the new COTS system can be called the "development gap".

No requirements specification templates for COTS implementation pre-existed in the company. Instead, the requirements specification was based on company templates for use cases and supplementary requirements specifications developed for new systems development. The project had difficulties specifying the necessary requirements on the new system. Perrone (2004) states that requirements engineering methods used for the development of systems built from scratch do not suit development using COTS systems. The requirements on COTS systems need to take into account the possibilities and constraints in the system.

A review of the requirements specification documents revealed weaknesses. There were comparably few requirements, and they were written on a high level. The requirements were based on the characteristics of the existing system, and did not align with the possibilities and constraints in the new COTS system. Some of the requirements were contradictory and requirements for specific technical areas were missing.

Further, requirements are dynamic and change, due to both internal and external reasons. Requirement changes will drive other changes. In the project, it became evident from the concept prototypes that the out-of-the-box release initially aimed at would require major customisations to meet GlobalGroup's needs. The project sent a system change request with additional functionality needed in the system, which VendorCorp agreed to include in their next system release. While waiting for the new release, the project continued at the same pace instead of slowing down, hoping to develop towards the available system release and upgrade to the new release when available. Rather, the project should have scaled down during the waiting period in order to follow the requirements dynamic.

All these issues made the requirements specifications difficult to use in reality. In fact, the requirements specification documents ceased to be used when entering the final development phase. The project then shifted to a test-driven mode, meaning that it was driven more by the response from system tests than from pre-defined requirements (cf. Morandotti, 2007).

4.4 System testing

New test case scenarios were constructed for the system testing. These were based on the use cases specified in the beginning of the project, but also included additional and altered functionality that appeared late in the project.

When using a test-driven approach, feedback from business representatives on early prototypes is necessary in order to guide further development. The system developers used several prototypes and business acceptance tests to evaluate their results with business reference group members and end users. But IT found it difficult to get relevant feedback in early phases. An explanation can be found in the degree of readiness at different stages of development. It is known that many people find it easier to have something tangible in front of them when testing a product, whether a physical product or an information system. Wiegers (2003) refers to this as IKIWISI – "I'll know it when I see it". Prototype evaluations were performed on presentation slides to the user community, while the business acceptance tests evaluated the complete solution in the real environment. Naturally, it is easier to give feedback on an almost complete system than on partial concepts on presentation slides. The testers needed to get used to the system first in order to give feedback. Although it was too late at this point to make major changes the early prototypes filled a purpose in announcing that there was going to be a change.

To facilitate feedback on early prototypes, focus needs to be put on communication between developers and the business reference group. However, the business reference group struggled with its own issues.

4.5 User involvement – the business reference group

The main forum for user involvement in the project was the business reference group.

Most of the communication between the IT project and the business divisions took place at the business reference group meetings. The group was led by the chief project manager, who also presented the group's views to the steering committee. At the reference group meetings, the IT project presented how far it had proceeded since last time and indicated what decision it needed by the business reference group.

Most of the business reference group members were from the headquarter site. They represented their own views, rather than those of the global organisation. Lack of time and compensation can be seen as an explanation for this issue, since business reference group activity was something done in addition to regular work. This was a known problem. Previous system implementation projects at GlobalGroup had tried to buy business reference group hours from business divisions in order to secure commitment. Unfortunately, the result had often been that business divisions hired consultants to do the work instead, with insufficient knowledge about processes or methods and with no contact network inside the organisation.

The business reference group members had too little knowledge of the possibilities and the constraints of the new system, making it difficult for them to describe the development gap. Instead, the IT project constructed most of the requirements and validated them with the business reference group to ensure that the processes had been correctly understood. Business reference group members were educated in the new COTS system, but the training was too short for its purpose. Several members were replaced during the project, and some new members were invited to join. Those who joined at a later stage did not receive the new COTS system training.

Unfortunately, GlobalGroup's project model for the development of information systems provided almost no guidance for how to set up, act in, or manage a business reference group. This made the project dependent upon the individuals' abilities in that area.

5 Discussion of research approach and usability of results

In this paper, qualitative findings from a multi-dimensional context are presented. The paper contributes with empirical experiences from a PDM implementation case, based on interviews, as well as project and company documents. Our findings have been presented for our business reference group at GlobalGroup and for interviewees that participated in the study. These presentations are part of the paper's validity construction (cf. Yin, 2003).

Transferability is an important evaluation criterion in single case studies (Guba and Lincoln, 1989). In this case, that means that the findings put forward can be transferred to the reader of the paper. Our intention has been to facilitate transferability by presenting a thorough description of the project, with rationale for courses of action, prior to the description and discussion of challenging PLM implementation aspects.

According to Svensson et al (2002), the generalisation of findings in qualitative, single case studies is possible through the recognition of the results. The findings have been presented for another company with characteristics similar to GlobalGroup's and the attendees did recognise and acknowledge most of the presented PLM implementation issues.

6 Conclusions & future work

This paper has presented an in-depth comprehensive description of how a PDM implementation project has been conducted. The paper discusses the rationale for different courses of actions and the effects those courses have had.

Challenging requirements management issues in this case included the following: the project scope and goals, the implementation process model, the requirements elicitation and validation, the system testing and the user involvement. Methods used to manage these tasks included a corporate project model, use cases, textual requirements, prototypes, various tests, and a reference group. However, they lacked a support for defining an overall scope and business case, for stating customisation rather than green-field requirements, for connecting use cases and tests and for making effective use of the reference group. Consequently, the project drifted from a pro-active, requirements-driven mode to a reactive, test-driven mode. A more skilled application of the requirements management toolbox could have resulted in a more successful project outcome, regarding time, cost and quality.

However, the project also demonstrates the importance of events beyond the project's control. A project scope and strategy with inherent contradictions, a delay of the target release from the vendor, and the need to adapt the launch to the group's product release schedule also caused significant delays and cost overruns. Well-performed requirements management activities are essential, but do not suffice, for a successful project outcome.

Findings from the paper can be used to validate published models for PLM implementation as well as in constructing new ones. Nevertheless, more empirical studies are needed, especially aspects concerning organisational change management, and the adaptation of COTS implementation models to the PLM context.

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