A Detailed Process Model for Large Scale Data Migration Projects

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Abstract. Data migration projects might sound exotic. They are not. Instead, they are common in all medium and large enterprises, e.g., when replacing applications with new (standard) software or when consolidating the IT landscape in the aftermath of mergers and acquisitions activities. General-purpose methodologies such as Scrum focus on managing projects. However, they do not discuss (data-migration) domain-specific tasks. These tasks are the focus and contribution of this paper. It elaborates and compiles them into a process-model. The model defines the logical and temporal dependencies between the tasks and clarifies roles and responsibilities in a migration project. Thereby, the variety of used know-how-sources sets this paper apart from any previous work in this area. We synthesize not only existing literature and own project experience in the German automotive and the Swiss banking sector. We also incorporate the results of twenty-five qualitative interviews from various industry sectors guaranteeing a high validity and applicability of our findings.

Keywords: data migration, project management, process model, deliverables.

1 Introduction

Data migration is a software-supported one-time process migrating data from a (supposed to be shut down) source to a target application with a typically different data model. It might sound exotic for many software engineers, but market shares prove the opposite. Application and system software development account for 9.35% of the global software industry. In contrast, the IT services industries account for 90.65% [1]. It centers on how to run applications or to commission applications successfully on the customer site. One aspect is data migration[1]. Large scale data migration projects which move a high volume of data while involving many different stakeholders have two main triggers. The first trigger is application replacements.

[1] In general, data migration competencies are seldom needed, often resulting in missing internal resources [4]. Moreover, migration tasks add to the daily-work load of staff. Together with being a non-business enabling project, this makes it sensible to rely on service providers.

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The data stored in the old system is transferred or migrated into the new one [2]. The second trigger is Mergers and Acquisitions (M&A) activities. In the process of consolidating redundancies, the data from the applications to be shut down has to be migrated to the "surviving" ones [3].

Comparing application development and data migration with sports means comparing a marathon with a 100 meters sprint race. Applications are long-living. They comprise thousands or millions lines of code coded by creative minds. Small mistakes are accepted and are corrected in later releases. In contrast, data migration comprises migration scripts, each possibly a few hundred lines of code. However, like a 100 meter sprint race, every small mistake leads to a complete failure. For instance, if a bank looses 0.1% of its customers during data migration, it is catastrophic. Thus, data migration is tested to be 100% correct or it is postponed. On the other side, nobody cares about deliverables after the data migration is completed. More technical details and challenges are discussed in previous publication [4, 5].

The aim of this paper is to take a project management perspective on data migration. Due to the needed high stability and reliability, we focus particularly on the process model and the various deliverables common to all projects. Complementing general-purpose project methodologies such as Scrum [6], we address two research questions:

Q1: Which process models for data migration do academia and industry suggest?

Q2: How does a detailed process model incorporating roles, deliverables, and phases for large scale data migration projects look like?

Throughout this paper we synthesize the various separate perspectives of the authors and their previous publications. The experiences come from the Swiss banking industry [2, 4], from data migration in the context of M&A projects [3], and from an interview-based study on the topic in various industries [7]. Additionally, this paper complements a previous joint paper on risk and quality assurance measures in data migration projects [5] by focusing now on processes for reducing quality risks.

The remainder of the paper is structured as follows: Section 2 addresses our research method. Section 3 outlines seven data migration approaches as found in academia and practice. We present the process model in Section 4 followed by an overview on the evaluation activities in Section 5. Finally, Section 6 concludes the paper with a short summary, a critical reflection, and an outlook.

2 Research Method

The goal of our research is the design of a detailed process model for data migration projects, i.e., an artifact which covers a broad scope while possessing a high level of detail. It must contain all important phases, roles, and deliverables. For understanding, executing, and evaluating the research we applied a design science approach adhering to the guidelines proposed by Hevner et al. [8]. The innovative artifact is designed to meet the business need, i.e., accessing semantically identical data with a different application. Figure 1 illustrates the artifact's input for the design and evaluation phase. For confidentiality reasons, we have omitted the real names of the experts

(indicated via gray circles and a sequence number) and their organizations. An intermediary result was the technical report [7] marking the transitioning from design to evaluation. In the following, Hevner's guidelines are shortly discussed.

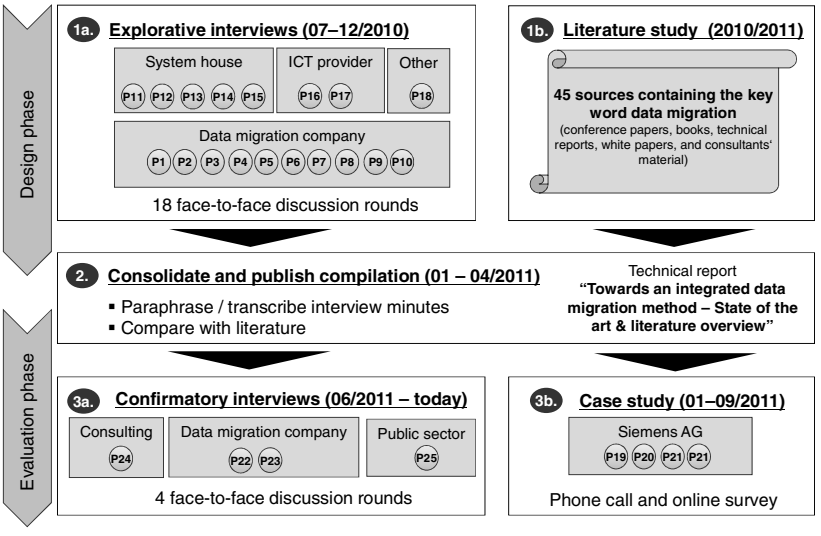

Fig. 1. Artifact's input for the design and evaluation phase

- Design as an artifact: Our process model is a method, thus a viable artifact being produced as part of the research. It guides data migration project participants in how to migrate data from a source to a target database.
- Problem relevance: A technology-based solution to migrate data is important as elaborated in the introduction section and literature (e.g., [2, 9]).
- Research contribution: To our knowledge, there is no detailed process model for data migration. The related work section contains a subset of sources we examined in 2010/11 by means of a systematic literature analysis. The study comprised 45 sources centering on data migration. It was conducted in parallel to the surveys and is partly published in [10]. Thus, the model provides a clear and verifiable contribution in the area of data migration.
- Research rigor: Besides the literature study, 18 data migration experts from six different companies in German speaking countries have been interviewed in half-day discussion rounds and on-site workshops between July and December 2010. The partners have been selected due to their domain knowledge following the idea of theoretical sampling[2]. The findings gained during these exploratory expert surveys have been systematically documented, transcribed, and consolidated. The result was a technical report [7] serving as a design foundation for our final process model.

[2] Theoretical sampling was introduced in the context of social research describing the process of choosing new research phenomena and to gain a deeper understanding [11]. It can be considered as a variation of data triangulation: using independent pieces of information to obtain better insights on something that is only partially known or understood.

- Design as a search process: Besides literature survey and interviews, the elements of the model date back to findings which we made in the course of several data migration projects in the financial industry. Achieved results have been previously published (cf. [2, 4, 5]).
- Communication of research: The process model is published in this paper to make it available to both management and technology.
- Design evaluation: Even though the model has its roots in industry experience we evaluated the artifact by means of four confirmatory interviews and a case study. Details are provided in Section 5 of this paper.

3 Related Work

Comprising more than 45 sources specifically centering on data migration, our literature study revealed that the topic is mainly addressed by practitioners. Most recent publications originate from consulting companies and tool vendors (e.g., [12, 13]). For this group, a data migration methodology is a competitive advantage. Hence, their approach often lacks details. This Section outlines the seven most detailed models from academia and industry focusing on their phases, deliverables, and roles.

Ground breaking work from academia is the PhD thesis of Aebi [9]. Subdivided in an explorative and execution part, the author presents the five-phase data migration model MIKADO. While the phases of problem analysis and definition are only conducted in the explorative step, preparation for and in the intermediate and target system also take place during execution. His work is technology-independent, proposes an intermediary staging area, and is supplemented by a tool architecture named DART. Describing the process of data migration on a general level Aebi refrains from pointing out concrete roles and deliverables.

Designed at Trinity College in 1997, the Butterfly Methodology is a method for migrating legacy information systems in a mission-critical environment [14]. Comprising six phases, the approach focuses on reducing the downtime of source and target application. The core idea is based on temporary databases which are sequentially set up, filled, and migrated to the target, before the next iteration starts (the number of data items declines over time). Presented phases outline key activities on a very high level only. The work centers on technical aspects, and, consequently, leaves out deliverables and roles of a data migration.

In their book Brodie and Stonebraker propose the Chicken Little strategy [15]. It is an incremental method which lets legacy and target systems interoperate during migration by using a gateway as a software mediating module. Pursuing a stepwise approach where the legacy applications are gradually rebuilt on the target platform, the strategy resolves into 11 briefly explained steps. Since emphasis is put on legacy migration in its entirety, only step 8 treats data migration details. Consequently, activities, deliverables, roles, or management aspects are not discussed. Finally, Wu et al. remark that gateways lead to the increase of the migration complexity [14].

John Morris looks at data migrations from a project management perspective based on various commercial data migration projects he was involved in [16]. The author elaborates on the stakeholders and key concepts of each data migration project. Bearing the name of his book, Morris' approach consists of four stages: project

initiation, data preparation (2x), and build, test, and go live. He defines precisely the activities and deliverables of each of those stages as well as the stakeholder in charge.

In cooperation with Informatica, The Data Warehouse Institute (TDWI) released a monograph about best practices in data migration [17]. Its main contribution consists in a seven-phase data migration process which covers several organizational and technical recommendations and is backed by a tool survey (Informatica, obviously, is a vendor in this area). Again, the author Philip Russom does not provide roles and deliverables needed in data migrations.

In 2007 Endava issued a white paper on key practices for data migration projects [12]. Targeted at migration project managers, it explains a set of key practices based on an 8-phase process. What sets this paper apart from others is the description of four roles: data migration project manager, data migration architect, business analysts, and testers. Endava provides a solid starting point without discussing technical, more data oriented aspects, specific tasks and roles, or deliverables.

Accenture advocates breaking down a migration project into a series of well-defined atomic level tasks, control metrics, and procedures that reduce cost and time to completion [13]. The distinctive feature of the work consists in the elaboration of concrete deliverables and roles (denoted key groups), even without giving a precise definition. In a nutshell, their process model has six phases which can be carried out in parallel. As a typical industry publication, the document remains on a very high level such that it only presents a short rundown on each phase. No refinements are made regarding roles and deliverables used during data analysis and transformation.

The above approaches represent a solid basis for the design of a detailed process model. However, our paper intents to go one step further. It provides empirically obtained information on phases, roles, and deliverables particular for data migrations.

4 A Process Model for Data Migration

In this section we describe the process model we devised rooted in on our own experience, statements from the data migration experts, as well as the literature study. The latter source is made explicit via references. Due to confidentiality reasons we cannot provide pointers to the industry experts. The success of a data migration project relies on many factors. One is clearly defined roles and teams. Below we list the most important ones, their tasks and responsibilities.

- The **business/program sponsor** initiates the migration project [13]. She/he clarifies the project scope, represents the business needs, and ensures the funding. Furthermore, the sponsor supervises the teams' project manager.
- The **customer core team** takes up the client's perspective. Many team members are business domain experts. They know the source application and understand how it contributes to the execution of the day-to-day business [16]. For this reason, they should be also employed as testers.
- The expertise of the **target application team** is the target application [15]. If the latter is replaced by a new one, building up a knowledgeable target application team might become a challenge. If there is already a target, the application management team and key users have to be involved [2].

- **Data migration team** is responsible for analyzing the data migration needs, implementing transformation rules, as well as running and testing them [12, 16]. This paper mainly focuses on their tasks.
- The **infrastructure and logistics team** provides infrastructure management services for the overall project [4]. They take over tasks such as managing the network, servers, database, or access rights. Certainly, the data migration team might manage specific data migration tools by themselves
- Some projects require the participation of **external auditors** for regulatory reasons [16]. In other cases, they participate at the discretion of the company. Auditors assess the process, project setup, migrated data, and reports. Their focus might not be on the migration alone but on the replacement project.

The process model (Figure 2) consists of four stages which are divided into phases yielding different deliverables. Stage one is the initialization phase for setting up the project organization and the technical infrastructure. Stage two is the development and stage three the testing phase. Often, both require several iterations until the migration is mature. This characteristic is accounted for with the help of the white arcs. In stage four the target application is put into operation.

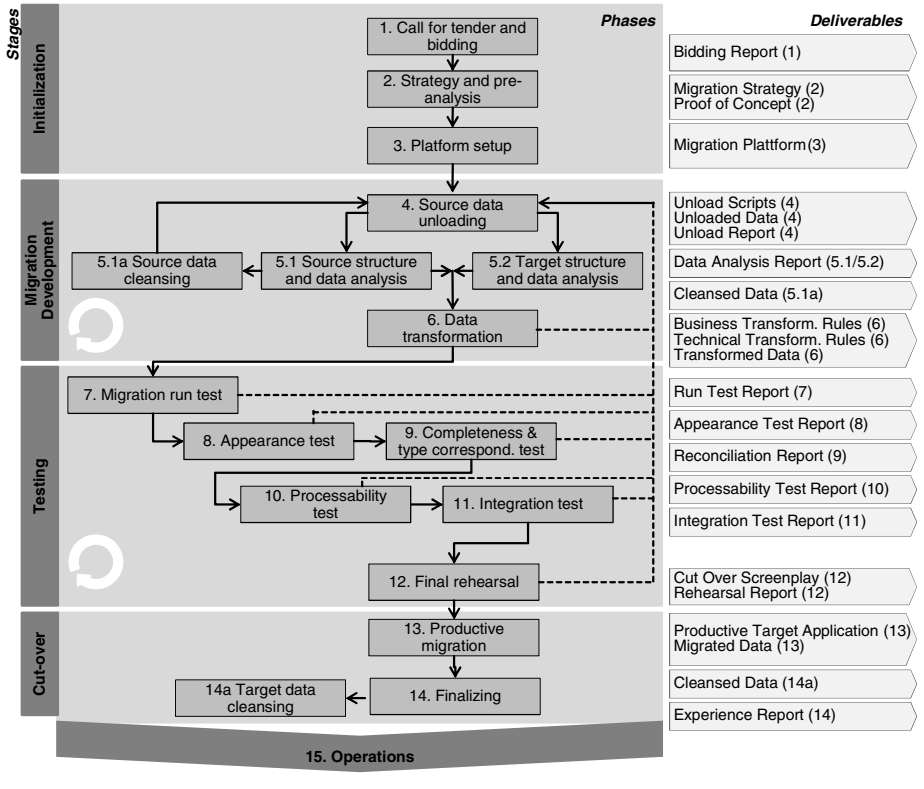

Fig. 2. Data migration process model

4.1 Stage 1: Initialization

Call for Tender / Bidding (1). Initially, it is not clear whether the newly formed IT department or an external IT service provider (and if so, which one) will take care of the data migration. This is the outcome of the first phase. Based on a customer questionnaire, preliminary data analysis, and their experience, the external company elaborates a bidding report. Pointed out as a necessity by our interview partners, the document clarifies the required resources, various risks, initial project planning, and the costs [7]. Most importantly, it covers the decision as to who has to take part in the project. Senior experts and managers from the company as well as from external service providers are involved in this phase.

Strategy and Pre-analysis (2). The primary outcome of this phase is a migration strategy defined by the data migration team together with the customer core and target application team. It refines the initial plan of the bidding report (e.g., big bang versus incremental approach [15] or how to cope with historic data in the source application [12]). The migration strategy covers also the organizational and technical constraints such as large data volumes, a target database already in use, proprietary interfaces, poor data quality, or distributed project teams. Furthermore, it details measureable acceptance criteria defining when the project is actually done. Depending on the time and the budget, a proof-of-concept with a small data set helps to raise the project morale and management support while allowing for a better cost estimation. A first prototype was mentioned by many of our interview partners [7].

Platform Setup (3). The data migration and infrastructure teams jointly set up the data migration platform and infrastructure respectively. While the former group is in charge of migration specific tools, the latter takes care of hardware, operating system, network, databases, etc. The data migration platform pursues two goals. First, is serves the data migration team for developing and testing the data migration scripts. Second, the test and the final migration run on this platform. The platform encompasses a staging area, an execution framework for orchestrating large numbers of data migration programs (semi-)automatically, a repository for the migration programs, and tools for developing data migration programs (cf. [2, 9, 17]).

4.2 Stage 2: Migration Development

Source Data Unloading (4). Unloading data from source to the migration platform must not hinder the daily operations on the still-in-use source application. Also, the unloaded data must be consistent over all modules. Often overlooked in the literature but valued as important among our interview partners, the unloading phase requires careful planning as to when and how to extract the data. After having planned the unloading, the customer core team (respectively the application management team) maps source and target data structures to the staging area, implements scripts (unloads are needed several times), and finally initiates the extract. The copying process might include some high level filtering, e.g., copy only master data and non-transactional data (cf. [2]). Furthermore, additional data not stored in the source but required by the target might be added, i.e., enriching. The outcome of this phase are the unload scripts, the actual (enriched) data downloaded to the migration platform unload

staging area, and a report with the number of unloaded data items. The latter is important to make sure that all data is going to be moved to the target.

Source/Target Data and Structure Analysis (5.1/5.2). The data models of the source and target application differ. Transformation rules implemented in the data migration scripts overcome this gap, but a profound understanding of the source and target data and structure is indispensable in beforehand. The analysis is mainly implemented by the data migration team [12]. Regarding data semantics and application knowledge, the team relies on the input of the customer core and target application team. In close cooperation, the three may unveil data quality issues which they document and assess. The outcome is a data analysis report which also includes necessary repairing work. As outlined by our interviewees, the document describes the source/target structure and the quality of the in-scope data on an attribute level [7].

Source Data Cleansing (5.1a). Any previously detected data quality issues should be cleansed to reduce the risk of future errors [16]. This can take place in the source application, during the transformation, or in the target application [12]. The latter two options entail the risk of more complex transformation rules. Therefore, cleansing should be performed directly in the source conjointly with the customer core team. In this way, the cleansing can be handled separately and performed by users of/on the source application. Final result is cleansed data meeting the target's requirements.

Data Transformation (6). The data analysis report compiled during phase 4 enables specifying and implementing the transformation rules. The interview partners explained that this is a two-step process [7]. First, the customer core team and the data migration team jointly formulate business transformation rules. These are an informal specification of the mapping of business objects types (e.g., customer, account) as well as tables and attributes between the source and target data structure. Second, the data migration team describes, implements, and tests technical transformation rules, e.g., using SQL or PL/SQL for relational databases. These rules also include data harmonization logic accounting for the data already residing in the target.

4.3 Stage 3: Testing

Migration Run Test (7). Before one can test migration scripts in detail, the infrastructure must work and the ordering of the migration of the business objects types must be defined. Furthermore, during the final productive migration, all data programs have to run smoothly within an acceptable time frame and respecting dependencies. Consequently, a migration run test, performed by the data migration team, validates exactly this. There are full and partial migration run tests. Full run tests validate the migration of all data [12]. If the infrastructure remains identical, the execution time should be the same as for the final migration. Migrating only parts of the data speeds up the migration but comes with higher consistency risks [5]. The deliverables is a run test report. It contains the logs with all error messages, crashes, and – in case of a full migration run test – the required execution time.

Appearance Test (8). The data in the source and target application must be semantically equal. The challenge is that both the data model and the representation of the data on the Graphical User Interface (GUI) differ between the source and target

application [2]. Business domain experts of the customer core team define a diverse set of data items of various business object types. On GUI level, they compare the test data items after each test migration (cf. [5] for a discussion on the risks of automating appearance tests). The outcome is an appearance test report. From a GUI perspective, it states for each data item of the test set whether it was migrated correctly.

Completeness and Type Correspondent Test (9). Data migration projects handle large amounts of data. The volume demands automation of the comparison of the data in the source and target, i.e., a reconciliation [4, 12]. Reconciliation scripts map primary keys (respectively identifiers) of the source and target applications. Thus, they identify whether data items got lost or emerged during the transformation and migration. The reconciliation is the only test covering all data items. This makes it sensible to consider also the types of objects on a high level. The implementation of the reconciliation and its execution after each migration test run is the task of the data migration team. Final deliverable consists in a reconciliation report containing all data items lost during the migration as well as all data items being emerged from nowhere.

Processability Test (10). Completeness and appearance on GUI level do not guarantee that the data can be processed faultlessly. There might be mandatory items which are missing and for which the GUI presents default values instead. However, the business logic of the target application might crash when processing the incomplete and/or default data. Other causes for problems are target application parameterizations being not compatible to the migrated data. The processability test addresses these challenges. The customer core and the data migration team specify which processes have to be tested and what kind of test data is leveraged for that. The tests can be executed manually on GUI level. In addition, application specific batch processes have to be applied (e.g., end-of-day or end-of-year processing). The result is a processability test set with batch processes and data items for their execution and a processability test report stating which processes could be executed correctly.

Integration Test (11). In most cases, the target application is embedded in an IT landscape consisting of a large number of interconnected applications. If the decision has been in favor of the migration, the business processes supported by the target application (including migrated data) and all connected applications must still function. This requires an integration test phase checking whether the references between the data in the respective target application and its neighbors work in both directions. Integration tests are end-to-end since they comprise the running of processes spanning over various applications including the newly migrated target application. The deliverables of the integration test phase are, first, an integration test set. It consists of a list of processes to be executed including the data items to be used. While the customer core and the data migration team have to work out this list together, only the former is required to carry out the tests. The second outcome is an integration test report stating which of the tests succeeded and failed respectively.

Final Rehearsal (12). An unsuccessful migration is expensive and a risk for the reputation of the enterprise. Thus, several final rehearsals are a last testing measure [13, 16]. It runs under the boundary conditions (e.g., hardware, course of action, amount of data) of the productive migration while making use of the same transformation rules. More precisely, the final rehearsal executes the data migration

with the transformation rules (phase 6) and an unload from the source system (phase 4) [12]. Next, it covers all tests from phases 7-11 in a condensed form. Thereby, every member of the data migration and customer core team performs exactly the tasks as they do later during the cut-over, i.e., the productive migration. The deliverables are a finalized cut-over screenplay serving as a blue-print. After the rehearsal, the data migration team works out a rehearsal report with all test results and unexpected events. This allows the management to decide whether the productive migration can be initiated as planned or whether additional adjustments have to be made.

4.4 Stage 4: Cut-Over

Productive Migration (13). The productive migration is the moment when the migration from the source to target application takes place [13, 15, 17]. Afterwards, the target application is released into production and the source is shut down. This is the point-of-no-return. A fall-back to the source application would be at expensive if impossible at all. Our interviewees referred to the convention of a final approval meeting with all team members [7]. The meeting decides whether the migration can start. The actual course of action consists of the tasks described in the phase 4, 6, and 7 to 11 and results in a productive and tested target which contains the migrated data.

Finalizing (14). The finalizing phase starts when the target application is up and running, i.e., all data has been successfully migrated and the end users work on the target [13, 16]. The target application team ensures adequate performance and stability. If this goal is achieved, the responsibility of the data migration team and all other project teams described above ends. They hand over the responsibilities to the application management team [17]. Our interview partners highlighted the importance of a short experience report compiled by the data migration team. It contains lessons learned which aim to ease future data migration projects [7].

Target Data Cleansing (14a). There are situations when not all data cleansing can be carried out in the source application or during the transformation. This is particularly the case for projects with a large amount of data and a very short time frame. Then, data cleansing should be done as soon as the target application is in production. This also comprises the manual adding of data, which could not be migrated automatically or was not originally stored in the source application.

5 Evaluation

As discussed in Section 2, the design of presented process model rests on three pillars. The first one is the authors' own experience and know-how gained during several data migration projects. The second is a literature review of 45 industry and research sources. Finally, the third pillar consists of interviews and workshops with 18 data migration experts already applying elements of the model.

Though the results being delineated in this paper largely originate from industry experience, we apply a two-step validation procedure. Firstly, we presented the model to experts who did not contribute to the original process design but are also well versed in data migrations. Since June 2011, we have organized dedicated meetings

involving four industry experts. Held at TU München or the expert's site, the meetings aimed at presenting, discussing, and validating the model. We captured the feedback via a confirmatory three-page questionnaire and incorporated most of the suggestions in the model. For instance, the partners convinced us to enhance our approach by focusing on concrete artifacts yielded in the course of a migration project. Also, they confirmed the model's suitability for large scale projects and proposed the inclusion of milestones, a fact that is accounted for by the four stages.

The second validation step consisted of an evaluation over a longer time period. In January 2011, we were introducing the model to Siemens AG being in charge of replacing the product life-cycle management (PLM) application of a German car manufacturer [10]. In detail, the application named Process Designer (PD) has to be replaced by TeamCenter Manufacturing (TCM) until 2016. Thereby, Siemens develops (and sells) both applications. TCM offers enhanced user management functionalities and allows for the versioning of its data. At the time Siemens approached us, the project was in the "Strategy and pre-analysis" phase seeking for an appropriate process model ensuring a smooth transition to the successor. Siemens asked for a sound methodology in addition to a literature survey of common data migration approaches. There was no data stored in the well-documented target. Although the documentation about the source's data is in poor condition, preliminary analysis revealed that the data itself is of very high quality. Carried out by a project team located at three sites, the migration will be conducted incrementally on a vehicle-basis. We outlined our process model to four Siemens experts during a 1.5h phone call. Afterwards, the employees had to fill out an online survey containing 50 confirmatory questions. The survey confirmed that our data migration process model is generally in line with the experience and expectations of the Siemens experts. Roles, deliverables, as well as the phases have been confirmed. The experts added that the cleansing could be integrated in the transformation activities.

6 Conclusion

In this paper, we presented a detailed process model for large scale data migration projects consisting of four stages. The model targets the needs of the IT service industry and its respective IT consultants. As external specialists, these consultants work on getting applications to run on their customers' IT infrastructure. The task covers the migration of data into the new applications. Listed deliverables defined for each phase provide guidance in this highly risk-averse domain.

This contribution centered on the fundamental challenges of data migration projects. Many more questions remain open and have to be addressed during future research. In our opinion, the most pressing ones are:

- Coping with migration series, e.g., when replacing several systems. Business needs the freedom to determine the exact date and portion of data being migrated while working on a consistent application landscape.
- Analyzing the cost-drivers of data-migration projects. This also encompasses questions like which phases and deliverables are especially important and which organizational choices help keeping overall costs low.
- Evaluating the model for various storage paradigms. Certainly, the process model is designed independently of the underlying database technology.

However, we have to confess that our sources and experiences mainly originate from projects with (object-)relational databases. Thus, it would be interesting to see how the needs for projects with, among others, XML databases, object-oriented databases, or video and audio databases differ.

Existing questions should not hide the contribution of our paper: a detailed process model for data migration projects. It combines an academic approach with practical experience by synthesizing knowledge sources ranging from own experience, literature, and migration experts. Finally, the artifact endured an intensive evaluation.

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