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Toward a Decision Model for Master Data Application Architecture

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Abstract

Requirements such as integrated view of the customer or global business process integration make enterprise wide management of master data a prerequisite for achieving business goals. The master data application architecture, as a part of enterprise master data management, plays a critical role in enterprises. Choosing the right master data application architecture is a controversial subject in many enterprises. Unfortunately, the current state of the art in research does not provide sufficient guidance for enterprises dealing with this subject. The paper aims at overcoming this gap in research by presenting a decision model for supporting enterprises in the decision-making process regarding the choice of the right master data application architecture. To design the model, Multiple-Criteria Decision Analysis and Design Science Research Methodology were applied.

1. Introduction

1.1 Motivation and problem statement

The need for better quality of data and information in enterprises has been one of the main drivers of ERP implementation in the last decade [3]. Based on it, master data management, being a part of enterprise information management, is receiving increasing attention both in the practitioners' and the scientific IS community [7, 29]. Master data represents the business objects used in different business processes. It is shared across the entire organization [7, p.35]. Typical master data classes are material, supplier, customer, employee, and asset data. These classes of data play a crucial role in fulfilling various strategic business requirements, such as the "360-degree view" of the customer [27], compliance with a growing number of regulations [6], mergers and acquisitions, or business partnerships with the need for globally integrated and harmonized business processes [17].

Master data management (MDM) refers to application independent processes for describing, owning and managing core business data entities of master data [29] . The objective of MDM is to ensure master data quality, such as consistency or accuracy, through a set of guidelines for master data management [7, p.5]. To this purpose, MDM creates a common view of company data, which may be stored in different data sources [29, pp.65-66]. This comprises different design decisions, such as identification of roles or assignment of responsibilities for management and use of data, as the focus of "Data Governance" [33], and choosing a suitable master data application architecture to be able to provide data across the entire organization [6, 15, 17].

Because of the strategic importance of master data, companies need to make their decisions regarding enterprise wide master data application architecture on solid ground. Therefore, companies need to be, or get, familiar with methods for designing application architecture and the corresponding design options for master data. Various aspects of enterprise architecture management have been discussed in the existing body of knowledge, and many widely accepted frameworks, such as The Open Group Architecture Framework (TOGAF), are devoted to data architectures and their components. However, one of the shortcomings of these frameworks is that they lack details regarding decision criteria and design in the master data application architecture domain. To overcome this situation, a comprehensive morphological analysis and a single-case study investigation were conducted by[21] and [24]. However, these studies do not provide any support for practical decision-making.

1.2 Research question and contribution

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There is a gap in research regarding the support of decision-making when it comes to choosing the right master data application architecture. The paper at hand aims to provide answers to the following research question: How should a decision model for choosing the right master data application architecture be designed? The paper follows the principles of Design Science Research (DSR) [9, 26] in order to design and evaluate a conceptual decision model for selecting suitable alternatives of a master data application architecture. The model is an artifact and the result of design oriented research [18, 19].

Every decision requires balancing of different criteria. In the data architecture context, mistakes and suboptimal decisions might lead to situations that cannot be easily revoked. The problem in this context is that one has to cope with a lot of information of complex and conflicting nature. Therefore, the paper uses Multiple-Criteria Decision Analysis (MCDA) [2] to support the decision-making process. One of the principal goals of MCDA is to help decision-makers organize this information, so that all criteria are properly taken into account [2, p.3].

2. Background

2.1 Master data and master data management

Enterprise data can be classified into master data, transaction data, and inventory data [11, 35]. Master data identifies and describes central business objects in an enterprise. Customer master data, supplier master data, and material master data are frequently cited examples [7, 17]. But also employee data, organizational data like cost center information, or shared charts of accounts are classified as master data.

Transaction data is data that is created in the course of business activities, i.e. it represents the input or output data of business processes. Examples of transaction data are purchase orders, invoices, or shipping notes. This class of data references master data and makes changes to inventory data [7, 31]. Inventory data refers to stock and account levels, e.g. to bank account balances or reserved stock of finished goods [23]. Figure 1 shows the interrelations between these data classes.

According to DAMA International [5], MDM pursues three goals: supporting business intelligence and information integration, lowering cost and complexity through standards, and providing an authoritative source of high-quality master data ('golden record'). Activities for achieving these goals comprise, among other things, understanding master data integration needs, managing changes in master data, defining and maintaining the master data application architecture, and identifying master data sources and contributors [21]. In this regard, MDM constitutes an 'application independent' [29] business function and does not refer to a class of information systems.

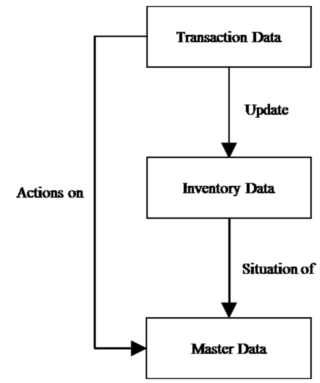

Figure 1: Interrelations between different classes of enterprise data [12]

As master data is used across the entire enterprise, MDM requires to be organized as a central or corporate wide function [23]. To this purpose, roles such as 'Data Steward' and 'Data Owner' need to be established to ensure 'Data Governance' in an organization [10, 17, 33].

2.2 Enterprise master data architecture

An 'architecture' is defined as "fundamental concepts or properties of a system in its environment, embodied in its elements, relationships, and the principles of its design and evolution" [13, p.2]. Based on this, an 'enterprise architecture' is specified by [13, pp.2-3] as "a coherent whole of principles, methods, and models that are used in the design and realization of an enterprise's organizational structure, business processes, information systems, and infrastructure". An 'information architecture' is a sub-architecture of information systems within the enterprise architecture, and a 'master data architecture' is considered as an information architecture that focuses on a specific data type, namely master data [24]. A master data architecture consists of two main parts: the conceptual master data model, which describes key business objects of enterprises and their relationships [5, p.63, 24], and the master data application architecture, which contains applications for creating, storing and updating instances of the master data attributes defined by the conceptual master data model [24, 36].

The paper focuses on the second part, the master data application architecture.

In practice and in research, one can distinguish between the following patterns of enterprise master data application architecture [4, 7, 14, 17, 21, 24, 30, 34]:

- *Central system:* Master data is created, maintained and updated in a separate, MDM specific application, from where it is distributed to connected, center-fed applications. It is a system of record, serving as the single version of truth for the master data it manages.
- *Leading system:* This pattern is frequently encountered in practice. One enterprise system is defined as the leading system for a data class. For example, the CRM system is the leading system for customer master data, and it provides this data to other business applications, such as ERP systems and web shops.
- *Service Oriented Architecture (SOA):* The rationale of this pattern is to distribute master data by means of services. Modification of master data is done by a service call-up. Thereby, an Enterprise Service Bus (ESB) is used.
- *Registry:* Master data is exchanged peripherally and bilaterally between applications. The registry does not contain the underlying dataset, but a minimal number of attributes needed to identify the master data object as well as a reference to the memory location of the related master data object in terms of metadata.
- *Consolidation hub:* This pattern brings together master data from a variety of systems (both databases and application systems) into a single, managed MDM hub. Along the way, the data is transformed, cleansed, matched and integrated in order to provide a complete 'golden record' for one or more master data domains.
- *Peer-to-Peer (P2P):* Applications work in a networked structure, in which all participants are equal with respect to what they are allowed to do. This pattern reflects the organizational structure of autonomous enterprises that directly and equitable share information and are responsible for the integration to their neighbor systems.

Data maintenance, data storage, and data distribution vary from pattern to pattern. Table 1 gives an overview of the different master data application architecture patterns described.

Table 1: Master data application architecture patterns

Architecture Pattern	Data Maintenance	Data Storage	Data Distribution
Central system	Central	Central	Push and pull
Leading system	Central	Central	Push and pull
SOA	Central	Central	Service call
Registry	Local	Central and local	Pull
Consolidation hub	Local	Local	Pull
Peer-to-Peer	Local	Local	Pull

2.3 Multiple-Criteria Decision Analysis (MCDA)

Multiple-Criteria Decision Analysis (MCDA) helps structure problems and seeks to take explicit account of multiple, conflicting criteria in aiding decision-making [2, p.5]. Therefore, MCDA in this paper is considered a tool or framework that helps solve decision-making problems regarding the master data application architecture. The purpose of MCDA in this paper is to evaluate master data application architecture alternatives regarding certain preferences.

The decision-making process based on MCDA consists of five steps [16]. In the first step, the problem should be defined. The input of decision-makers and experts needs to be incorporated at the beginning of the problem formulation stage. The second step focuses on alternatives capable of addressing the problem defined in the first step. These alternatives are generated through involvement of decision-makers and experts. In the third step, the criteria need to be identified by which the alternatives should be assessed. These criteria need to be developed by decision-makers and experts. The fourth step is about gathering value assessments on the relative importance of each criterion. Quantitative criteria weights are obtained from decision-makers and experts. In the final step of the decision-making process, the most suitable alternative is selected. The alternative is chosen by systematic, well-defined algorithms using criteria scores and weights.

3. Research approach

3.1 Research context

The need for doing research on this topic results from the reported shortcomings of the existing body of knowledge regarding master data application architecture design decisions. The research context is formed by a collaborative research program named

Competence Center Corporate Data Quality (CC CDQ) at University of St. Gallen in Switzerland, which is a consortium research project [20]. Since 2006, researchers, together with a number of partner companies, have been developing solutions and designing artifacts in the field of MDM in general and master data application architecture in particular. The design process follows the principles of the Design Science Research Methodology (DSRM) [26].

3.2 Research process

Focus groups were used for definition and design of the results. In addition, expert interviews have been conducted to demonstrate and evaluate the provided solution.

As proposed by the DSRM process model, the design of the artifact was carried out in six steps. The first step, which was carried out between June and December 2011, aimed at identifying the problem and the motivation of the research. Our research was mainly motivated by practitioners who continuously articulated the demand for support with regard to design decisions in the process of choosing the right master data application architecture. Furthermore, our research was motivated by the gap we identified in the scientific body of knowledge.

The second step in the research process was about the definition of the objectives of the solution. The objectives of our research resulted from the identification of the challenges in practice and the realization that the existing knowledge base did not deliver appropriate responses to these challenges. The results of this step were confirmed by a focus group (focus group A) comprising 23 participants from 13 large companies. Table 2 gives an overview of the composition of focus group A, which took place in Manchester, UK, on November 25th, 2011.

Table 2: Overview of focus group A

Industry	Number of companies	Number of participants
Chemical	3	5
Pharmaceutical	2	7
Automotive	1	1
Telecommunication	1	1
Consumer products	2	4
Manufacturing	3	4
Oil	1	1

The third step comprised the design activities, which followed the general principles of modeling presented by [1, 28, 32]. The design process was carried out in two iterations. The first version of the decision model was built on the basis of an integrated state-of-the-art analysis including a literature review. The second iteration was based on the results of the assessment of a second focus group (focus group B), comprising 27 representatives from 14 companies and taking place in Basel, Switzerland, on April 18th, 2012. Table 3 gives an overview of the composition of focus group B.

Table 3: Overview of focus group B

Industry	Number of companies	Number of participants
Chemical	2	4
Pharmaceutical	2	4
Software	2	3
Manufacturing	5	12
Consumer products	2	3
Insurance	1	1

The fourth step of the design process aimed at demonstrating the applicability of the decision model. For this purpose, seven expert interviews were conducted between May and August 2012.

In the fifth step, the decision model was evaluated. Activities included expert interviews and multi-perspective evaluation according to the guidelines proposed by [8].

The sixth step comprised communication activities. The DSRM results had to be communicated in the practitioners' and the scientific community [9, 26]. The practitioners' community was addressed mainly by presentations at conferences. To make the results of our research available to the scientific community, the paper at hand was drawn up. It presents the conceptual decision model that can be used, extended, and further evaluated by future research.

Figure 2 summarizes steps one to five of the research process.

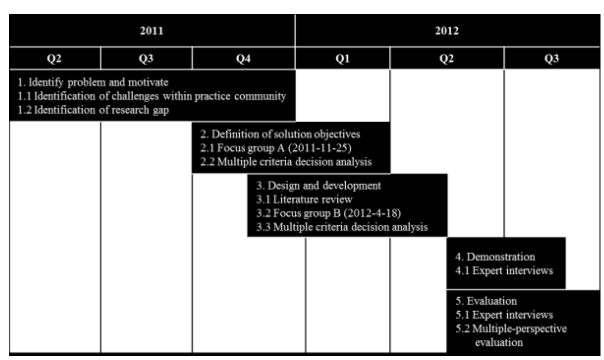

Figure 2: Overview of research process

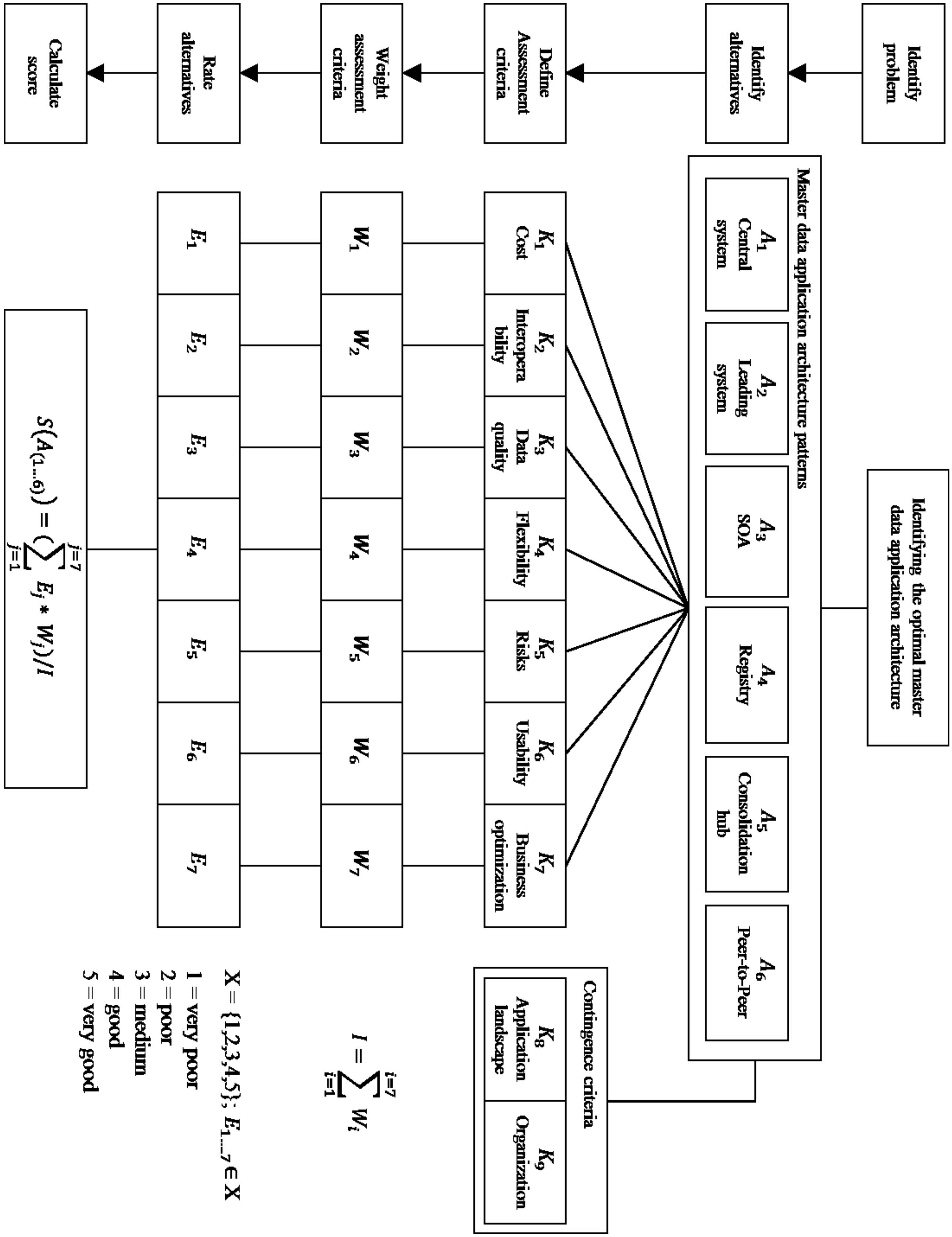

Figure 3: Decision model for master data application architecture

4. Design of the decision model

4.1 Overview

Figure 3 shows the decision model for choosing the right master data application architecture. The design of the model is based on the decision process defined by MCDA [16] and consists of a 6-level structure. The first five levels represent the five steps as described for the decision-making process (see 2.3). In the last (sixth) step of the decision model, a formula can be used to calculate a score for different architecture alternatives. The model's structure was designed during focus group discussions with both company management and application architecture experts; all related to master data architecture activities. The model was continuously reviewed and adapted within the design science research (DSR) [25] process. The six levels are described in the following:

Identify problem. Identifying the right master data application architecture is a problem in many enterprises. The main motivation for building the decision model was to offer enterprises support in this process and make the decision-finding process more efficient and easier.

Identify alternatives. A literature review identified six master data application architecture patterns (see 2.2). These patterns were discussed and reviewed by the first focus group on November 25th, 2011. They represent possible alternatives of master data application architectures. Every decision-maker has to choose between one of these alternatives, taking into consideration the company's requirements and his/her own decision criteria.

Define assessment criteria. For identification of the optimal solution, various decision criteria have to be considered. These criteria need to be provided by decision makers that have a clear overview of all fundamental and crucial factors for making decisions regarding master data application architecture. The criteria were defined by the two focus groups and were then completed during the demonstration phase by means of expert interviews. Seven criteria ($K_{1\ldots7}$) were identified that are the basis for evaluating and assessing the alternatives identified on the second level. The focus group discussions also showed that the search for the right application architecture depends on two contingency criteria (K_8 and K_9). Contingency criteria are individual and enterprise specific and cannot be evaluated on a scale. Therefore, the calculation of the score for each architecture pattern is based on non-contingency criteria only.

The identified criteria are defined as follows:

- ***Cost*** comprises all possible expenses for implementation, maintenance, infrastructure and hardware.
- ***Interoperability*** covers the possible level of automation for data exchange with different applications.
- ***Data quality*** represents the level of various quality dimensions, such as completeness, accuracy, consistency, timeliness, etc. described by [22].
- ***Flexibility*** comprises the ability to adapt to changing requirements.
- ***Risks*** refer to system complexity, robustness, and stability.
- ***Usability*** comprises simple operability and user-friendliness.
- ***Business optimization*** considers the potential for improving business results and performance.
- ***Application landscape*** is a contingency criterion and represents the as-is state of the system landscape.
- ***Organization*** is a contingency criterion and comprises the type of the organization and the management of responsibilities for MDM (e.g. local vs. central).

As already mentioned above, the last two criteria were identified as contingency criteria that do not play a direct role in the score based evaluation of application architecture patterns.

Weight assessment criteria. How the importance of each criterion is assessed varies from one expert or decision-maker to the other. Therefore, weighting criteria helps ascertain the importance of a criterion when it comes to evaluating an alternative. For this purpose, I as a parameter for weighting criteria should be defined (e.g. 100 points). The decision-maker or expert then has to assign a proportion of I to each criterion, depending on how important they consider it to be, so that at the end of the weighting process all weights can be added up to I. The higher a criterion is weighted, the more important is it in the evaluation of master data application architecture.

Rate alternatives. The decision-maker or expert has to rate each master data application architecture alternative against the defined criteria on a scale between 1 = 'very poor' to 5 = 'very good'.

Calculate score. The last level of the decision model provides a calculation of the score of each master data application architecture alternative. The calculation is based on the weights and ratings of the fourth and fifth level, respectively. As this calculation is based on non-contingency criteria only, decision-makers have to include the influence of the contingency criteria in their decision process, so that the right decision can be made.

4.2. Model demonstration

The decision model was demonstrated in the course of six interviews with experts from different companies. Table 4 gives an overview of the interviews conducted. Table 5 shows which master data application architecture patterns are used by which company.

Table 4: Overview of interview participants

Company	Industry	Revenue 2012 in €	Number of employees
A	Chemical	39.7 billion	111,500
B	Manufacturing	52.3 billion	305,000
C	Consumer products	5.5 billion	16,600
D	Chemical	13.3 billion	26,000
E	Telecommunication	58.2 billion	232,300
F	Automotive	17.4 billion	74,800

Table 5: Master data application architecture patterns in use

Comp.	Central system	Lead. system	SOA	Regis.	Con. Hub	P2P
A	X					
B	X					
C	X	X		X	X	
D	X			X		
E	X	X	X	X	X	
F	X				X	

As Table 4 shows, none of the companies taking part in the survey uses the peer-to-peer architecture pattern. In general, this pattern is hardly used by enterprises. Hence, it was left out during the expert interviews.

Six experts were all ‘global architects’ responsible for MDM in their respective company. Each company has been interviewed once. The interview took 90 minutes and was recorded in writing and then transcribed, analyzed and evaluated afterwards. The interview process was as follows:

1. The five master data application architecture patterns were introduced by the interviewer. The interviewee was then asked whether they consider this selection of patterns complete or if they wanted to add any missing patterns.
2. The criteria by which the architecture alternatives should be assessed were introduced by the interviewer. The interviewee was then asked whether they consider this selection of criteria complete or if they wanted to add any missing criteria.
3. The interviewee was asked to weight the criteria according to their importance.
4. The interviewee was asked to rate each alternative against the defined criteria.

After the interview, a ranking of master data application architecture patterns was prepared, based on the calculated scores. The ranking was discussed with the interviewee in a separate session, which took between 15 and 30 minutes. The purpose of this session was to discuss and confirm the results of the preceding interview. As a detailed view of the results would clearly go beyond the scope of the paper, the paper gives only an overview of the results.

As already mentioned, interviewees were asked to prioritize the criteria. Table 6 depicts the result of this prioritization based on the weighting parameters defined by each expert.

Table 6: Prioritization of criteria

Criteria	Expert					
	A	B	C	D	E	F
Cost	o	+	++	o	+	++
Interoper-ability	-	-	o	+	+	++
Data quality	++	-	+	++	++	++
Flexibility	+	o	++	o	+	++
Risks	-	-	o	o	o	++
Usability	o	-	o	o	o	++
Business optimization	++	++	+	+	++	++

Key: -- very low; - low; o medium; + high; ++ very high

The majority of the six interviewees considered data quality and business optimization as the two most relevant decision parameters for choosing the right master data application architecture. However, there was also one interviewee (expert B) who said that if business optimization was given, data quality would not play a significant role. Surprisingly, cost was often mentioned as secondary for the decision. This view can be related to the type of companies that were examined, as all of them are large companies and probably less interested in the cost of a solution than in its applicability and value proposition for the company. Flexibility was ranked similar to the cost factor. Interoperability, usability, and risks were ranked less relevant by most of the interviewees.

As in the interview process mentioned, the interviewees were asked to rate all application architecture patterns against the identified criteria. Table 7 shows an aggregation of the rating results from all interviews.

Table 7: Aggregated evaluation results

Criteria	Central system	Lead. system	SOA	Regis.	Con. Hub
Cost	--	-	--	-	+
Interoper-ability	o	o	o	o	+
Data quality	++	++	+	-	-
Flexibility	-	-	o	+	+
Risks	o	o	-	o	o
Usability	--	o	o	+	o
Business optimization	o	o	o	++	++

Key: -- very poor; - poor; o medium; + good; ++very good

From these rating results, some general strengths and weaknesses of each pattern could be identified, which are listed in Table 8.

Table 8: Strengths and weaknesses of master data application architecture patterns

Pattern	Strengths	Weaknesses
Central system	High data quality	High cost Poor flexibility Poor usability
Leading system	High data quality	High cost Poor flexibility
SOA	High data quality	High cost High risks
Registry	High flexibility Very good usability High level of business optimization	High cost Poor data quality
Con. Hub	Low cost High interoperability High flexibility High level of business optimization	Poor data quality

The patterns with a central approach seem to provide high data quality, but are associated with high cost and poor flexibility. Inversely, the patterns with a local approach are more flexible and provide a high level of business optimization, but are characterized by poor data quality.

Table 9 shows how the six experts ranked each master data application architecture pattern based on the calculated scores. The results show that for all cases a central approach (either leading system or central system) fulfills the evaluation criteria. However, it should be considered that the two contingency criteria remained disregarded in this evaluation. These criteria can have a very strong impact on the selection of the right architecture pattern. For example, if a company is characterized by a very local, distributed structure, it would make little sense to decide in favor of a central approach.

Table 9: Ranking of master data application architecture patterns

	Expert					
	A	B	C	D	E	F
1	Central system	Central system	Lead. system	Lead. system	Central system	Lead. system
2	Regis.	Con. Hub	Central system	Central system	SOA	Con. Hub
3	Lead. system	Regis.	Con. Hub	SOA	Con. Hub	Regis.
4	SOA	Lead. system	Regis.	Regis.	Regis.	Central system
5	Con. Hub	SOA	SOA	Con. Hub	Lead. system	SOA

It should also be noticed that the decision model was applied to six cases only. This means that the results and the assessment could look totally different in the case of other enterprises depended on their criteria rating and weighting. But the ranking should help as an orientation for decision makers of the participated companies to know the limitations, capabilities, strengths and weaknesses of each pattern. It should be considered as an instrument for supporting their decisions based on their preferences.

As already mentioned above, the results were discussed with each interviewee in a second session. All experts confirmed the results. They all emphasized the crucial role of the two contingency criteria, which could not be taken into account because of their complexity and individuality.

5. Multi-perspective evaluation

[8] provides a framework for evaluation which comprises four perspectives. This framework is now used for the evaluation of the decision model presented in this paper. The perspectives for evaluating the decision model are as follows:

- ***Economic perspective.*** Due to the simple structure of the model (the six steps based on MCDA) and clearly defined objectives, the costs for adaptation and application of the model are low. Tools supporting the decision-making process can be created at low effort (e.g. Microsoft Excel based templates for documentation). Using the decision model does not lead to direct cost savings, but making the right decision can help prevent unnecessary future costs. Both the focus group assessments and the expert interviews have shown that the decision model is capable of simplifying the exchange of knowledge.

- ***Deployment perspective.*** The focus group assessments and the application of the decision model in the enterprises have shown that the model is easy to understand and well applicable. Any rejection of the model due to the fact that it was developed externally (the 'not-invented-here' syndrome) could not be observed.
- ***Engineering perspective***. The simple structure of the decision model ensures easy adaptability [8].
- ***Epistemological perspective***. The validation of the model by applying it in the enterprises has shown that the model is capable of abstracting and representing reality. Critical distance is ensured by explication of use cases. Moreover, explication of the decision model design process ensures that scientific principles are followed (such as verifiability and reproducibility of the artifact).

6. Summary and Outlook

The paper presents a decision model for supporting decision-making regarding the choice of the right master data application architecture alternative. The process of designing the artifact (i.e. the decision model) included the six steps as proposed by the design science research methodology. The research process consisted of two design cycles and one evaluation cycle.

The decision model is beneficial with regard to the advancement of both the scientific state of the art and the state of the art in practice. The description of the design process and of concrete design decisions allows scientific validation of the artifact as well as its extension by aspects previously not sufficiently considered or differentiated. Due to limitations of space, related organizational roles and result documents were not taken into consideration in this paper.

The demonstration of the decision model has shown that master data application architecture patterns with a central approach are better with regard to data quality. Unfortunately, however, the same patterns cause high costs for enterprises. The architecture patterns with a local approach provide more flexibility and have the potential to improve business results, but they are also characterized by poor data quality.

The main contribution of the paper is to offer enterprises support by providing a decision-making instrument that helps simplify and organize the process of selecting the right master data application architecture. However, the future research should also consider the two contingency criteria identified and focus on a more structured integration of these contingency criteria into the decision-making process. To do so, three case studies are planned to apply the decision model in a real environment.

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