A Use Case-oriented Framework for the Evaluation of In-Memory IT-Systems

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Abstract—**After a comeback in recent years, In-memory systems are now among several candidate solutions to solve future IT challenges. Despite the increased interest in the technology, however, there is a hesitant spread. One reason could be the lack of practical application scenarios that decision makers can apply to their business context. The aim of this work is to introduce a framework to support the evaluation of potential In-memory applications. Relevant factors that influence a possible In-memory use were evaluated using the Multi-Attribute Utility Theory approach, accompanied by an expert survey and therefore create a base for the framework. The framework is then used to evaluate 10 complex real-world In-memory use case scenarios. The results show that the presented approach in this work is suitable to both assess possible use cases and determine cases with high potential.**

Keywords*–*In-Memory IT-Systems; Business Value; Analytic Hierarchy Process (AHP); Multi-Attribute Utility Theory.

I. Introduction

Enterprises are faced with the challenge of constantly growing data volumes, increasing competition pressure and the permanent need to instantly react to events. This is one of the main reasons why choosing the"'right"' IT-systems has become a major strategic decision for companies. The selection of the appropriate system may determine the success of a company or in other words, the selection of the wrong system might lead to serious business disadvantages [1]. The challenges and possibilities associated with the term Big Data characterizes today's IT landscapes. In this context, In-Memory IT-systems (IMIS) represent a key technology [2]. Despite promising expectations, the technology has not yet been significantly established in the industry. Companies mainly criticize the lack of reproducible use cases [3][4]. Since the beginning of the boom of the technology, a whole series of application scenarios have been propagated. Based on these examples, which were often tailored to specific sectors and fields of application, many companies could not derive their own benefits and lead in-memory techniques to fruition. According to a study by the consulting company Pierre Audoin Consultants [5], many companies see great potential in the technology, yet there are only a few cases where the benefits are exploited. This is interesting in contrast to the expectations placed on the technology to create business value along all steps of the value chain. This accounts for a vertical integration, as well as a horizontal. In addition to these open issues in the corporate sector, there is a clear need for a generalizable reference model to analyze and evaluate in-memory scenarios [6][7] from a scientific perspective. Hence, a universal evaluation tool is needed to determine whether IMIS is beneficial or not suited in a specific scenario and vice versa.

The decision whether to use an IMIS in a company or not is a complex and multi-criteria decision problem. Beside IT requirements numerous other aspects like the relation with, i.e., employees, customers or suppliers have to be considered. Furthermore, possible massive change in the company's infrastructure [8] has to be evaluated. The representation of this complexity requires a corresponding model which covers all these different aspects. In this work, we will therefore introduce a framework which reflects both the industrial as well as the scientific claims. We will create a design science based system, able to identify and evaluate potential IMIS scenarios. Due to the versatility of the IMIS technology and its potential use in different use cases, the scenarios may strongly differ among each other. Some aspects may be specific and unique, meaning only relevant for a certain scenario. These aspects are directly linked to the creation of business value and are therefore called value-creation dependent. On the other hand there will be aspects of a scenario that are not directly linked. These are called value-creation independent. According to their specific characteristics the weightings of the value-creation independent factors are determined by the analytic hierarchy processing and the dependent factors are determined by the direct ranking method. The evaluation and interpretation of the presented framework is based on 10 cross-industrial use cases.

The paper is organized as follows. Section II introduces the research background, the existing literature in the field of IMIS and the overall structure of the framework. Section III presents the research methodology including the analytic hierarchy process (AHP) and the direct ranking method (DRM). In section IV the application of the framework is shown. The final section summarizes the contributions of this work.

II. Research Background

For a better understanding of the evaluation framework it is necessary to gain a deeper understanding of the technical characteristics of IMIS. The idea of using main memory for the storage of data goes back to the 1980's [9] and 1990's [10]. Caused by the high costs and relatively low storage sizes IMIS was basically a niche technology in the past years. With the introduction of the SAP HANA platform [11], the technology experienced some kind of a comeback. Originally, the SAP HANA platform was developed for accelerated and flexible analysis of large data sets. This new generation of IMIS includes a totally different storage concept in comparison to relational databases. The data in In-Memory Systems is mainly stored in a column-based manner [12]. The advantage is a better data compression [13][14], due to the fact that the data of the same type is stored in a column. In the recent years the focus on analytical tasks has been extended to hybrid IT-systems. The idea is to store the operational and analytical data entirely in a main memory database [15][16]. These hybrid systems are referred to as Online Mixed Workload

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Processing (OLXP) [17] and Hybrid Transactional/Analytical Processing (HTAP) [18]. Common data storage expansive and time consuming extract, transform, load (ETL) processes from the transactional into the analytical system are no longer necessary [13]. As a result, operational data can be used for analysis without major time delays.

Due to the different characteristics of analytical and operational tasks, problems and difficulties arise for hybrid systems. The column-based storage of data was originally designed for read-oriented and read-only analysis tasks. A higher proportion of write access typically characterizes operational systems, i.e., enterprise resource planning systems. The merging of these two approaches is often associated with complex join procedures [19]. In read-oriented environments, this can reduce the maximum possible performance improvement promised by IMIS.

A. Problem Context and Related Work

The majority of the early publications in the field of IMIS were characterized by the strong focus on rather technical aspects. To a great proportion, only technical features, such as the column-based storage of data [12], data compression [14] or the persistence of volatile storage media [20] were investigated. The dominance of technical investigations still illustrates the strong technologically driven development. Despite it's potential, only few studies about the evaluation of IMIS use cases have been published to date. The first studies in this field have been carried out by Piller and Hagedorn [6][21]. The authors evaluate first case studies in the retail sector. The case studies were evaluated with the aid of various influencing factors. Based on the factors, first application patterns were derived. Another approach to characterize and classify in-memory systems was presented by Winter et al. [22]. They identified stereotypical patterns based on the data volume and the degree of hybrid workload. An alternative approach for the analysis of In-memory applications addresses the business process characteristics of IMIS use cases. Pioneers in this area were vom Brocke et al. [23][24][25]. They developed a value-creation model, which considers first- as well as second-order effects. They conclude that the value-creation is closely related to process change. The evaluation of several IMIS use cases by Bärenfänger et al. [26] confirmed this results. Another approach focused on the cost benefit effects of IMIS. In this context, Meier et al. developed a model for the economical evaluation of IMIS. Like vom Brocke et al. they distinguish into direct and indirect benefits. In their publication, [27] Ulbricht et al. tried to combine the findings of the different approaches. They presented a structured model for the evaluation and analysis of IMIS use cases, taking various factors into account. Despite the different focuses, one thing all approaches have in common. They all consider the characteristics of IMIS use cases from a quite abstract level. The degree of dissemination in individual sectors, however, indicates the different importance of the particular influencing factors. The question arises, why this technology has already been used quite frequently in some sectors and is hardly ever noticed in other areas.

B. Approach

As mentioned before, the evaluation and analysis of IMIS use cases is a complex, multi-criteria decision problem. In order to represent and solve the decision problem the model of the multi-attribute utility theory (MAUT) is used. This model allows to consider both the system requirements as well as the corresponding importance. To determine the total utility U, the additive model (1) of the MAUT [28] is applied. In this model the system requirements are represented as x_i and the significance (importance) as w_i.

$$U = \sum_{i=1}^{n} w_i x_i \quad (1)$$

In order to provide a better complexity handling, we characterize the several influence factors and bring them into a hierarchy in a first step. In the second step, we select suitable methods for the determination of the significance depending on the characteristics of the influence factors. The different characteristics of the factors lead to a trade off between the operability of the methods and the quality of the results. In the final step, we reveal the results of the utility methods and evaluate the overall framework based on 10 case studies. In this part we demonstrate the feasibility of our concept. The creation of the framework follows the concept of the design science research [29]. Both practical and theoretical aspects are considered in the design process. The several steps of the design process are shown in the following sections. The created artifact is represented by a framework. The overall approach is summerized in Figure 1.

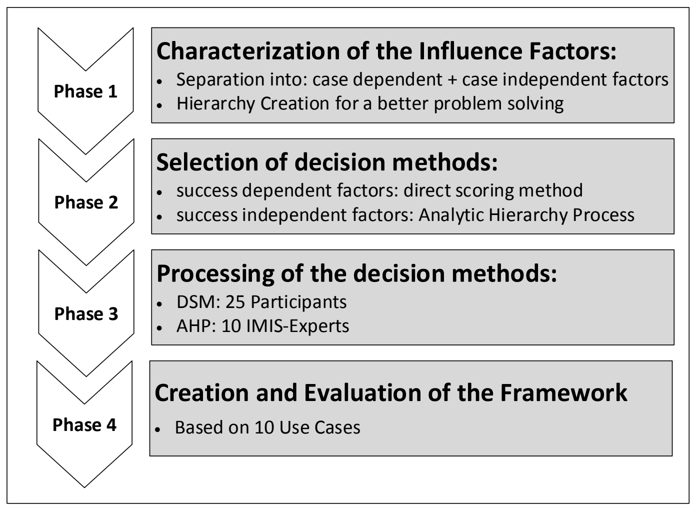

Figure 1. Overview of the Research Methodology

C. Characterization and Categorization of the Influence Factors

In [8], DeLone et al. divided the influencing variables of information systems into success dependent and independent. Analogous to this approach we categorized the influence factors in our framework into value-creation dependent and independent. The whole categorization is presented in the following section. The starting point of the considered influence factors is the IMIS evaluation model from Ulbricht et al. [27]. An overview of the developed framework is given in Figure 2.

1) Value-creation-dependent influence factors: This category includes the factors, which are most relevant for the value-creation of a use case. Due to the strong impact on the business success, they are particularly important for corporate decisions. These factors comprise the internal as well as the external realization conditions, e.g., the capability to realize the results from the IT-system in an appropriate time. Another influence factor is the potential benefit regarding the use of IMIS. This means value-creation through faster data processing or more detailed analysis. In most cases, business value is the most important decision criteria for companies. In this consideration, this point also includes non-monetary benefits and second-level effects like an improved customer satisfaction. In order to achieve independence of the factors, it is important that the potential value generation is considered independent of the other factors. Independence is the prerequisite for the later conducted application of decision methods [30].

2) Value-creation-independent influence factors: This category includes factors which are from a solely business perspective of minor importance. This means that these factors have no direct relation to the value-creation. An economically oriented decision maker is in most cases not interested in the underlying data volume or the data structure. On the other hand, these factors play a very important role for the technical evaluation of In-Memory Systems. In order to consider all relevant aspects for the evaluation, company representatives, scientists as well as IMIS vendors are involved in the determination of these factors. In addition to these stakeholder-oriented factors, this category also includes technical aspects, which are related to the value-creation. These include, for example, the frequency of change and the range of variation. One of the probably most important advantages of IMIS is the capability of fast data processing. Expert interviews and case studies in this area have shown, however, that the requirements regarding, e.g., the urgency vary significantly between different business areas.

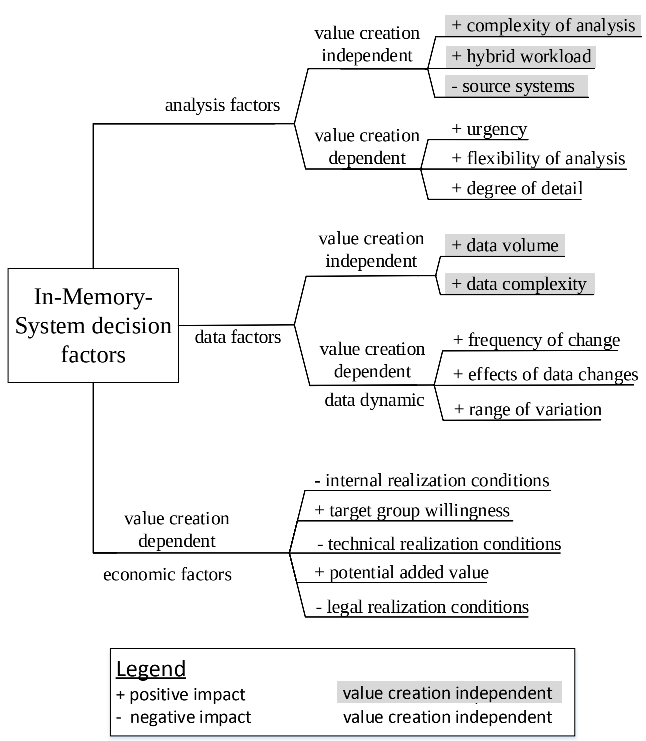

Figure 2. Overview of the analysis and evaluation framework (adapted according to [27])

III. Research Methodology

After the basic features of the framework have been described in the previous section, the question arises how the respective relevance regarding the evaluation of IMIS is represented. For this purpose, an additional weighting factor is added to the framework. The respective weights are determined by selected multi-critical decision-making methods. The directly scoring method is used for the value-creation dependent factors. To determine the significance of the value-creation independent factors the AHP method is utilized. The selection criteria and methodology are explained in the following section.

A. Direct Ranking Method

The direct ranking procedure is one of the simplest methods for the determination of the importance of attributes. At the same time, this method produces the least accurate results of the weight determination methods. In practical environments, the direct ranking is frequently used because of its simple and fast applicability. Compared to other procedures, it is not possible to check the consistency or plausibility of the answers. The evaluation is carried out by assigning ordinal scaled preference values. In our framework, we use a range from 1 to 10 for the scale. Due to the normalization of the values, the range of the scale is of minor importance. The weighting of the particular factors is obtained by dividing the individual preferences p_i by the total sum of the preferences. The equation for the determination of the weighting is shown in 2.

$$w_i = \frac{p_i}{\sum_{i=1}^{n} p_i} \tag{2}$$

In spite of the missing methodological variety the direct ranking method suits well for the usage in corporate environments due to its simple applicability. For these reasons, this method was selected for the determination of the value-creation dependent influence factors. To determine the independent parameters more complex methods are necessary.

B. Analytic Hierarchy Process

The analytic hierarchy process, developed by Saaty [31], is a widely used method for multi-criteria decision problems. This method has been applied in comparable decision problems like the selection of enterprise resource planning [32] or the selection of software as a service products [33]. It uses a pairwise comparison of the alternatives to determine ratios and scale priorities. The factors are judged on a 1 to 9 scale. Each factor is compared with every other factor. This kind of comparison improves the decision making within sophisticated problems. On the other hand, with numerous alternatives this leads to an increasing complexity. To reduce this, the alternatives are divided into hierarchies in the AHP. A major advantage with this method is the possibility to check the results for inconsistencies. Through the avoidance of inconsistent answers, it is possible to obtain qualitative better results. However, this requires an increased degree of attention from the participants of a study. The explanation of the particular calculations is omitted at this point.

Despite the relatively simple use of pairwise comparisons, the AHP method can produce reliable results. Due to the high complexity and the high demands placed on the participants, this procedure is only to a limited extent suitable for the

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utilization in companies. The AHP was chosen to determine the significance of the value-creation independent influence factors. As in already mentioned, a total of 10 experts from different sectors participate in the assignment of these factors. The possibility to detect inconsistent answers helps to ensure the quality of the results. Through the existing segmentation of the framework into hierarchies, the complexity of the decision problem can be reduced.

IV. Application of the Framework

In this section, we present application examples of our IMIS evaluation Framework. For the evaluation of the framework we conducted and analyzed 10 case studies. Thereby, a wide range of companies were involved. This includes, for example, a smaller IT service provider, a medium-sized online travel provider up to a large retailing company. For reasons of space, we only present the results of 3 use cases. The characteristics of the use cases are shown in table I. Aimed by the characteristics the evaluation becomes more comprehensible. In the first part, we determine the weightings of the influence factors, applying the direct ranking method and the AHP. Afterwards, we demonstrate the results of the case studies.

TABLE I. Characteristics of the analyzed Use Cases

			Local Weight Use Case 1	Local Weight Use Case 2	Local Weight Use Case 3
Category	Factor		Analysis of POS-Data	Real-Time Reporting	Finance Reporting
Analysis	Urgency		Few minutes	Near real-time	Near real-time
	Flexibility of analysis		Ad-hoc	Standard	Standard
	Degree of detail		Medium	Very detailed	High
	Hybrid workload		Yes	Yes	Yes
	Complexity of analysis		High	Very high	Medium
	Source systems		2	1	2
Data	Data volume		Extremely high	Extremely high	Medium
	Data complexity		Only structured data	Mostly structured	Mostly structured
	Data dynamic				
		Frequency of change	Rarely	Frequently	Frequently
		Effects of data changes	Low	High	High
		Range of variation	Moderate	Strong changes	Moderate
Economic	Internal realization conditions		Months or longer	Hours	Days
	Potential added value		High	Very high	Medium
	Target group willingness		Medium	High	Medium
	Technical realization conditions		Low	Low	Medium
	legal realization conditions		Only little regimentation	No regimentation	Highly regimented

A. Weightings for the Value-Creation Dependent Factors

To determine the business-related significance of the value-creation dependent factors, it was necessary to include only experts with an appropriate extent of knowledge in the field of data analytics. Therefore, we asked corporate representatives in senior analytic-aware IT positions to rank the importance of each IMIS influence factor. The application of our framework is shown based on 3 selected use cases. The sample use cases have been chosen considering their business and technical characteristics. So, it is possible to illustrate all aspects of a IMIS use case evaluation. The resulting weightings of the use cases are shown in table II.

It becomes clear that the significance of the influence factors vary only a bit in the analysis and data categories.

TABLE II. Weightings of the value-creation dependent Factors

Category	Factor		Local Weight Use Case 1	Local Weight Use Case 2	Local Weight Use Case 3
Analysis	Urgency		0.306	0.316	0.304
	Flexibility of analysis		0.421	0.367	0.353
	Degree of detail		0.272	0.316	0.342
Data	Data dynamic				
		Frequency of change	0.286	0.333	0.300
		Effects of data changes	0.286	0.333	0.400
		Range of variation	0.429	0.333	0.300
Economic	Internal realization conditions		0.177	0.204	0.239
	Potential added value		0.431	0.442	0.324
	Target group willingness		0.104	0.119	0.140
	Technical realization conditions		0.190	0.219	0.257
	legal realization conditions		0.098	0.017	0.039

Significant differences can be seen within the economic factors. As easily predictable, the potential added value is the most important attribute. Nevertheless, the weighting varies quite strongly. The relatively high influence of the other factors illustrates the need for an overall assessment.

B. Weightings for the Value-Creation Independent Factors

As already mentioned in section III-B, the mainly technologically driven factors are more complex in their examination. A one-sided investigation from a business perspective does not cover all relevant aspects. It is necessary to involve a broader field of knowledge and experience in this consideration. For this reason, we have included both business experts, scientists and experts from system providers to determine these factors. A strength of the conducted AHP method is the possibility to detect inconsistent answers. The unanimous opinion about the consistency is that only answers with a consistency ratio lower or equal 0.1 has to be considered. For this reason, in each category 2 responses had to be excluded. The aggregated results of the AHP in table III reveal that for the evaluation of the value-creation independent analysis factors the complexity of analysis and the hybrid workload have the main impact. The amount of source systems is in this context only of minor importance. A quite more notable tendency can be seen between the data volume and the data complexity. For the evaluation of the value-creation independent data factors the data volume plays is most relevant.

TABLE III. Weightings of the value-creation independent Factors

Category	Subcategory	Subcategory Weight	Factor	Local Weight
Analysis	Value-Creation independent	0.38	Complexity of analysis	0.42
			Hybrid workload	0.44
			Source systems	0.14
	Value-Creation dependent	0.62		
Data	Value-Creation independent	0.55	Data volume	0.81
			Data complexity	0.19
	Value-Creation dependent	0.45		

C. Evaluation Examples

The first chosen example comes from an early adapter of IMIS systems. The analysis of point of sales data in the retail section is one of the first examples in this area. The company participating on our case study is one of the leading

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retailers in Germany. For reasons of space and legibility we only show some key attributes of the example. The example is characterized by a high demand regarding the urgency, data volume and the complexity of analysis. The calculation includes transactional as well as analytical tasks. Due to the rare and minor data changes, the requirements in this area are quite moderate. The most important obstacle concerning the realization of the potential added value is the long implementation duration.

The second example from the insurance area is characterized by very high requirements in the analysis as well as in the data area. For this use case, it is necessary that the results are based on up-to-date data and are processed in near real-time. The analyzes are based on large amounts of data directly from the transaction system. From an economic point of view, this case is characterized by a very high added value. There are neither internal nor external obstacles that avoid the realization of the results. For this reasons, this example is assessed very high in all categories.

The last example shows very clearly the diverging significance of the influencing factors. The use case comes from a supplier company in the medical field. This company uses IMIS to improve their financial and controlling reports. Despite relatively small changes to the data base, it is important that the data is up-to-date and the results of the analyzes are available very quickly. In comparison to the other use cases, the overall technical requirements are a bit smaller. The same is true for the economical factors. Especially the high legal regimentation stifle/obstruct the economical assessment.

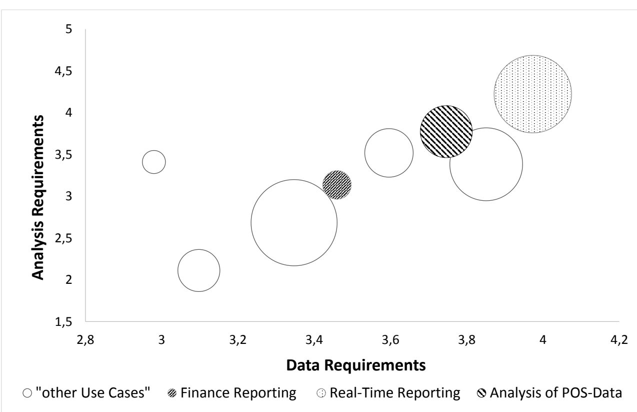

Figure 3. Results of the Use Case Analysis

For a better clarity and easier interpretation we assigned the results of the use case evaluation to a portfolio chart (Figure 3). This chart is comparable to the strategic portfolio matrix of the Boston Consulting Group [34]. The advantage of this chart is the possibility to have a visual indicator for the evaluation of the complex underlying decision problem. The dimensions of the chart are based on the categories of the presented framework. The analysis and data requirements are building the axes of the chart. The radius of a data point reflects the economical assessment as seen in Table I. The chart is an easy to use tool to indicate promising use cases. As seen in Figure 3 the assessment of the use cases is quite diverse. The use case Finance Reporting for instance may be characterized by a rather low economical assessment on side, having medium to low data and analytical requirements on the other side. Although an assessment of a use case scenario is still subjective to the decision maker's assumptions and weights, the chart provides a tool to either choose, rule out or change possible use cases. This may also lead to the decision to only use IMIS in parts of the originally planned scenario or to switch to substitute technologies. So, the process of the application scenario definition, which could be a repetitive process, may also be supported by the framework.

V. Conclusion

Recent research as well as practical applications of In-memory systems has shown a research gap concerning the structured consideration of IMIS use cases. To address all relevant aspects regarding this consideration, a multi-criteria decision framework was introduced. Previous IMIS examples have shown a strongly varying importance of the individual influencing factors. In order to map all factors and their significance, a multi-attribute utility theory model was used. In addition, the factors were subdivided into the two categories value-creation dependent and value-creation independent. The methods for the determination of the weightings were selected according to these categories. The presented framework allows to examine existing, as well as exemplary future use cases with regard to the influence factors of In-memory based IT systems. The approach allows to consider both, the system requirements and the corresponding importance. This makes it possible for decision-makers to investigate IMIS scenarios for their application potential.

In future work, the framework should be extended to other industries. A broad selection framework is also conceivable that shows reasonable conditions for the use of the In-memory technology. With the aid of the framework, catalogs could be created for suitable and tested application scenarios.

References

[1] J. Peppard and J. Ward, "Beyond strategic information systems: towards an is capability," The Journal of Strategic Information Systems, vol. 13, no. 2, 2004, pp. 167–194.

[2] "Top 10 Hot Big Data Technologies," 2016, URL: https://www.forbes.com/sites/gilpress/2016/03/14/top-10-hot-big-data-technologies/ [accessed: 2017-07-11].

[3] "SAP fehlen echte HANA-Business-Cases," 2015, URL: http://www.cio.de/a/sap-fehlen-echte-hana-business-cases,2940526 [accessed: 2017-07-24].

[4] "Lack of SAP HANA use cases stifling demand among ASUG members," 2014, URL: http://diginomica.com/2014/08/08/lack-sap-hana-use-cases-stifling-demand-among-asug-members/ [accessed: 2017-07-24].

[5] "SAP Business Suite powered by SAP HANA," 2014, URL: https://www.pac-online.com/download/9757/125462 [accessed: 2017-07-12].

[6] G. Piller and J. Hagedorn, "Business benefits and application capabilities enabled by in-memory data management." in IMDM, 2011, pp. 45–56.

[7] R. Schütte, "Analyse des einsatzpotenzials von in-memory-technologien in handelsinformationssystemen." in IMDM, 2011, pp. 1–12.

[8] W. H. DeLone and E. R. McLean, "Information systems success: The quest for the dependent variable," Information systems research, vol. 3, no. 1, 1992, pp. 60–95.

[9] H. Garcia-Molina and K. Salem, "Main memory database systems: An overview," IEEE Transactions on knowledge and data engineering, vol. 4, no. 6, 1992, pp. 509–516.

[10] D. J. DeWitt, R. H. Katz, F. Olken, L. D. Shapiro, M. R. Stonebraker, and D. A. Wood, Implementation techniques for main memory database systems. ACM, 1984, vol. 14, no. 2.

[11] F. Färber, S. K. Cha, J. Primsch, C. Bornhövd, S. Sigg, and W. Lehner, "Sap hana database: data management for modern business applications," ACM Sigmod Record, vol. 40, no. 4, 2012, pp. 45–51.

[12] D. J. Abadi, P. A. Boncz, and S. Harizopoulos, "Column-oriented database systems," Proceedings of the VLDB Endowment, vol. 2, no. 2, 2009, pp. 1664–1665.

[13] H. Plattner and A. Zeier, In-memory data management: technology and applications. Springer Science & Business Media, 2012.

[14] D. Abadi, S. Madden, and M. Ferreira, "Integrating compression and execution in column-oriented database systems," in Proceedings of the 2006 ACM SIGMOD international conference on Management of data. ACM, 2006, pp. 671–682.

[15] H. Plattner, "A common database approach for oltp and olap using an in-memory column database," in Proceedings of the 2009 ACM SIGMOD International Conference on Management of data. ACM, 2009, pp. 1–2.

[16] A. Kemper and T. Neumann, "Hyper: A hybrid oltp&olap main memory database system based on virtual memory snapshots," in Data Engineering (ICDE), 2011 IEEE 27th International Conference on. IEEE, 2011, pp. 195–206.

[17] P. Loos, J. Lechtenbörger, G. Vossen, A. Zeier, J. Krüger, J. Müller, W. Lehner, D. Kossmann, B. Fabian, O. Günther et al., "In-memory-datenmanagement in betrieblichen anwendungssystemen," Wirtschaftsinformatik, vol. 53, no. 6, 2011, pp. 383–390.

[18] M. Pezzini, D. Feinberg, N. Rayner, and R. Edjlali, "Hybrid transaction/analytical processing will foster opportunities for dramatic business innovation," Gartner (2014, January 28) Available at https://www. gartner. com/doc/2657815/hybrid-transactionanalytical-processing-foster-opportunities, 2014.

[19] D. J. Abadi, "Query execution in column-oriented database systems," Ph.D. dissertation, Massachusetts Institute of Technology, 2008.

[20] T. Winsemann and V. Köppen, "Kriterien für datenpersistenz bei enterprise data warehouse systemen auf in-memory datenbanken." in Grundlagen von Datenbanken, 2011, pp. 97–102.

[21] G. Piller and J. Hagedorn, "In-memory data management im einzelhandel: Einsatzbereiche und nutzenpotentiale," in Multikonferenz Wirtschaftsinformatik, 2012.

[22] R. Winter, S. Bischoff, and F. Wortmann, "Revolution or evolution? reflections on in-memory appliances from an enterprise information logistics perspective." in IMDM, 2011, pp. 23–34.

[23] J. vom Brocke, S. Debortoli, and O. Müller, "In-memory database business value," 360 - The Business Transformation Journal, vol. 3, no. 7, 2013, pp. 16–26.

[24] J. vom Brocke, "In-memory value creation, or now that we found love, what are we gonna do with it?" BPTrends, vol. 10, 2013, pp. 1–8.

[25] J. vom Brocke, S. Debortoli, O. Müller, and N. Reuter, "How in-memory technology can create business value: insights from the hilti case," Communications of the Association for Information Systems, vol. 34, no. 1, 2014, pp. 151–167.

[26] R. Bärenfänger, B. Otto, and H. Österle, "Business value of in-memory technology–multiple-case study insights," Industrial Management & Data Systems, vol. 114, no. 9, 2014, pp. 1396–1414.

[27] S. Ulbricht, M. Opuszko, J. Ruhland, and M. Thrum, "Towards an analysis and evaluation framework for in-memory-based use cases," in The Twelfth International Multi-Conference on Computing in the Global Information Technology. IARIA, 2017, pp. 22–27.

[28] G. P. Huber, "Multi-attribute utility models: A review of field and field-like studies," Management Science, vol. 20, no. 10, 1974, pp. 1393–1402.

[29] A. R. Hevner, S. T. March, J. Park, and S. Ram, "Design science in information systems research," MIS quarterly, vol. 28, no. 1, 2004, pp. 75–105.

[30] R. Klein and A. Scholl, Planung und Entscheidung. Vahlen, München, 2004.

[31] T. L. Saaty, "What is the analytic hierarchy process?" in Mathematical models for decision support. Springer, 1988, pp. 109–121.

[32] C.-C. Wei, C.-F. Chien, and M.-J. J. Wang, "An ahp-based approach to erp system selection," International journal of production economics, vol. 96, no. 1, 2005, pp. 47–62.

[33] M. Godse and S. Mulik, "An approach for selecting software-as-a-service (saas) product," in Cloud Computing, 2009. CLOUD'09. IEEE International Conference on. IEEE, 2009, pp. 155–158.

[34] D. C. Hambrick, I. C. MacMillan, and D. L. Day, "Strategic attributes and performance in the bcg matrixa pims-based analysis of industrial product businesses1," Academy of Management Journal, vol. 25, no. 3, 1982, pp. 510–531.