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
Phase 1
Selection of decision methods:
- success dependent factors: direct scoring method
- success independent factors: Analytic Hierarchy Process

Phase 2
Characterization of the Influence Factors:
- Separation into: case dependent + case independent factors
- Hierarchy Creation for a better problem solving

Phase 3
Processing of the decision methods:
- DSM: 25 Participants
- AHP: 10 IMIS-Experts

Phase 4
Creation and Evaluation of the Framework
- Based on 10 Use Cases

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.

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.

\[
w_i = \frac{p_i}{\sum_{i=1}^{n} p_i}
\]

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
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

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

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 analytics-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. 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.

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
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.

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


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


