Towards an Analysis and Evaluation Framework for In-Memory-based Use Cases

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***Abstract*—The aim of this work is to introduce a framework for the analysis and evaluation of potential In-memory applications. As a base for the framework, relevant influencing factors for the use of In-memory systems were identified. For the evaluation and the identification of further influencing factors, an expert survey was carried out. The results show that aspects relevant to companies were not considered in the past. Therefore, a structured analysis framework is introduced considering also economical factors. The use of the framework and the interpretation of the results will be clarified in the end using selected fields of application.**

Keywords–In-Memory IT-Systems; Big Data; Business Value; Case Study; In-Memory Computing.

I. INTRODUCTION

In December 2014, Amazon introduced the ”Prime Now” service, which guarantees the delivery of several thousands of products within an hour [1]. In the field of high frequency trading, fractions of a second can determine profit or loss [2]. Sociologists have been talking about this subject as the ”age of acceleration” for quite some time [3]. Never before in history were decision makers forced to make entrepreneurial decisions under greater time pressure than today. Furthermore, increasingly huge and heterogeneous data sets are challenging companies. One of the most promising technologies for solving these challenges are In-memory-based IT systems (IMIS). Although the technology was subject to high expectations in the past, the predicted boom has not yet begun. In this context, many companies complain about the lack of useful and economical application scenarios [4][5]. In a study by the American SAP user group, this point is mentioned as one of the main causes for the delayed distribution [6]. The reasons for this is, among others, the previous focus on technical aspects [7]. A study by the market research company PAC [8], on the other hand, shows that the In-memory technology is of great interest to many companies and can play an important role in the future. 36% of the surveyed company representatives see this technology as an important building block in future IT landscapes. In this field of tension, it becomes clear that the In-memory technology has great potential that has not yet been exploited.

In this work, we will introduce a design science based system, able to identify and evaluate influential factors for potential application scenarios of IMIS. The aim of this approach is to examine existing as well as potential future scenarios. Based on an analysis framework, the requirements and their feasibility of use cases are examined. In order to identify possible influencing factors of In-memory application scenarios, case studies and scientific literature are analyzed. Subsequently, the influence factors found are evaluated with the help of field experts who participated in an expert survey, also identifying yet unknown and additional factors.

The paper is organized as follows. Section II introduces the technical background, the existing literature about IMIS and the general methodology. Section III presents in the first part the results of the literature review and the expert survey. In the second part of section III the conceptual framework is introduced and its application is shown. The final section summarizes the contributions to practice and research.

II. RESEARCH BACKGROUND

The idea of using main memory to store data is not new. These concepts were introduced in the 1980s and 1990s [9][10]. At that time, the main focus was very fast response times which were realized by main memory databases. Due to high costs and low memory sizes, the interest regarding In-memory databases decreased and the technology almost fell into oblivion. With the introduction of the HANA platform [11], SAP has once again placed the focus on IMIS. The previous concerns about the durability of the stored data could be eliminated by the use of non-volatile RAM [12]. The concept of IMIS includes more than a pure data storage in the main memory. In contrast to conventional relational databases, the data is no longer stored row-based, but mainly column-based [13]. The advantage of a column-based storage is on the one side a better data compression and on the other side a better suitability for analytical tasks. Originally, the main application area of IMIS were fast and flexible analysis of large amounts of data in data warehouses. In the meantime, the application areas were extended to transaction systems. The goal here is to dissolve the historically grown separation between online analytical processing (OLAP) and online transaction processing (OLTP) systems [14][15]. These hybrid systems are referred to as Online Mixed Workload Processing (OLXP) [16] and Hybrid Transactional/Analytical Processing (HTAP) [17].

The advantage of a common data storage is the elimination of ETL processes from the OLTP into the OLAP system. In addition, transactional data can be used for analytical and planning tasks. Furthermore, there is a potential for savings through the elimination of an additional system [18]. However, it is important to note that analysis and transaction systems have fundamentally different characteristics and requirements [19]. Analytical systems are generally used for the support of specialists and executives. Decisions at these company levels are, in most cases, characterized as strategically or tactically, that means for a longer period. The data access during the execution of analyzes are almost exclusively read-only [19]. On the other hand, transaction systems are used to solve everyday business tasks of a company. In most cases, the time horizon only covers a relatively short period [20]. The typical transactional workload is also largely read access, but compared with analyzes, with a significantly higher

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proportion of write accesses [19]. The merging of OLAP and OLTP systems to an OLXP / HTAP system leads not only to the advantages mentioned, but also to problems and difficulties. From a technical point of view, hybrid workloads (line / column-based & read / write) must be simultaneously processed [21][22][23]. The merging process also leads to a stronger dependency on the respective system provider. In order to be able to exploit the entire benefit of an IMIS, a large number of applications and processes have to be adapted.

IT providers, such as SAP have predominantly driven the hype surrounding the In-memory technology in the past years. The focus of recent developments was mostly technology-oriented. Similar tendencies can be found in early scientific work in this field. Mainly technical features, such as the column-based storage of data [13], data compression [24] or the persistence of volatile storage media [25] were investigated. An alternative approach for the analysis of possible In-memory applications tries to assess the advantages and potentials on the basis of business requirements. In the first papers in this area [26][27] Piller and Hagedorn are investigating factors for evaluating In-memory applications. The authors examine the potential of IMIS in the retail sector. Despite the early maturation phase of this technology at the time of the investigation, initial application patterns have already been identified.

Similar results are also reported by Cundius et. al in their work [28]. They developed a model for evaluating real-time IT systems. The focus of this work was on the workflow-specific properties of real-time IT systems. The use of IMIS not only has an impact on data processing, but also on the downstream decision-making and implementation processes. Vom Brocke et. al examine the connection between the In-memory technology and the resulting business use in their papers [29][30][31]. They conclude that a value-creation for companies is strongly related to the adaption of processes. Vom Brocke et al. as well as Bärenfänger et al. [32] conclude that the introduction of In-memory technology not only leads to a direct benefit, but to a large extent to downstream improvements in the process flow. Meier et al. further pursue the aim of an economic evaluation in [33]. They also divided the economic effects into direct and indirect attributable effects.

One of the most important innovations of IMIS is the combination of analysis and transaction systems. Winter et al. analyze the properties of IMIS in one of the first case studies [34]. In addition to the volume of data, the integration of the analysis and transaction system is identified as the most important indicator for the assessment of IMIS. This point is also highlighted in several other scientific papers in this field [16][26][27][35]. From a solely technical perspective, IMIS offers huge potential. However, the question arises for which companies or application areas this potential can be exploited in practice. For many companies predefined reports and evaluations on a daily basis will still be sufficient. For others, the use of real-time data can become a decisive competitive advantage. Previous application examples often refer to very specific or exotic tasks. A popular example of the application of IMIS is the analysis of sports data, e.g., in Formula 1 [36] or soccer [37]. Although these examples are quite illustrative, they are not suitable to provide insights into the solution of ”everyday” business problems. The lack of economical use cases is regarded as one of the main obstacles to the distribution of IMIS. This is mentioned in science literature [26][35][38] as well as from a company point of view [4][7].

III. A Framework for the Evaluation and Analyses of In-memory based IT systems

The aim of this research work is to examine and structure IMIS use cases with regard to their success factors. Based on these factors an analysis and evaluation framework has been developed as seen in Figure 1. The methodology described by Klein and Scholl [39] was used to define the overall structure of the framework. The main advantage of the used methodology is the avoidance of structural defects during the modeling phase. Hereby, it is possible to develop a well-designed and feasible decision model. For this purpose, the scope of the model was first restricted in order to consider only the aspects, which are relevant for the problem solving. After the relevant influential factors were identified, they were subdivided through a structural analysis. As a result of this structuring process, an operationalizable target system for assessing and analyzing In-memory use cases has been created. The

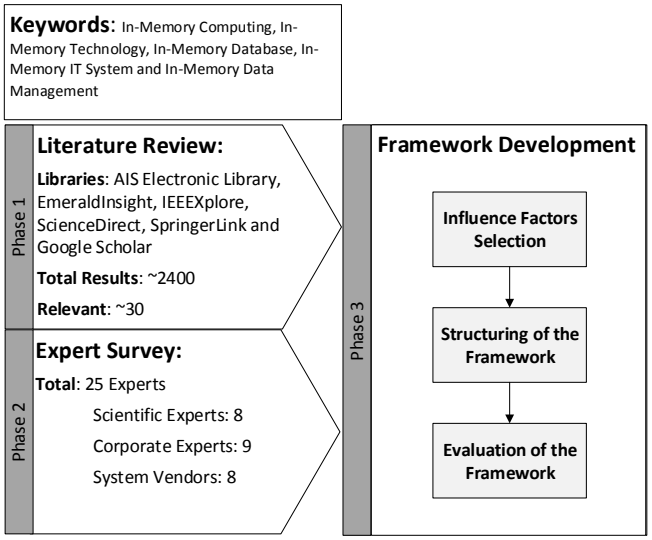

Figure 1. Illustration of the research methodology

methodology of Design Science Research was used as the base for the framework. The advantage of this approach is that the dynamic characteristics of business needs can be directly taken into account. The design process is not static, it allows changes to be incorporated into the existing model [40][41]. In order to gather the basic factors influencing the framework, scientific work and previous case studies in the field of IMIS were analyzed and evaluated during the first design phase. In terms of research method, this was accomplished according to Webster and Watson [42]. In the literature review, established literature databases (AIS Electronic Library, EmeraldInsight, IEEEXplore, ScienceDirect, SpringerLink and Google Scholar) were investigated. The search included the following key words: ”In-Memory Computing”, ”In-Memory Technology”, ”In-Memory Database”, ”In-Memory IT System” and ”In-Memory Data Management”. Subsequently, a backward search was carried out. Therefore only papers dealing with the application and the business perspective of IMIS were used. The study of the literature databases revealed that around 2400 scientific publications have so far dealt with IMIS. Due to the context of this paper only publications with an business perspective were

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considered. Hence, 30 relevant papers remained. The detailed results are explained in the next section. During the second design phase,as seen in Figure 1, a qualitative expert survey [43] was carried out to evaluate the results and identify further factors. In particular, the expert survey was carried out to reveal further findings on challenges from an economic point of view. In order to cover a broad range of opinions and experiences, the experts were composed of representatives from different fields. Totally 25 experts in the field of IMIS were interviewed. These included scientists, company representatives as well as representatives of leading IMIS providers. In semi-structured interviews the experts were asked about the potential and the obstacles of the In-memory technology. In addition, the experts were asked to evaluate possible application scenarios and their characteristics in detail. In the final step, the application of the model will be presented using selected In-memory use cases from the retail sector.

A. Results of the literature and case study review

The examined works used different approaches to deal with the analysis and assessment of the scenarios. The work [26] by Piller and Hagedorn has proven to be a suitable basis for the model presented in this work. Starting from the business process characteristics described in this study, further influencing factors were identified and classified. In the following, the examined factors are presented and explained.

Main memory-based databases are often mentioned to solve the challenges which are associated with so called Big Data applications. Due to the availability of larger main memory and advanced compression by the column orientation, IMIS is able to process large amounts of data [18][44]. Therefore, it is appropriate to include the data volume of a use case into the consideration. Apart from the data volume, a number of other factors play a decisive role. These include, for example, the urgency of the results [26][27][31][45] or the dynamics of the data [26][27][28]. Hence, high-performance systems have a strong positive effect if the data changes frequently. If the underlying data changes only very rarely and to a small extent, the potential additional value of a real-time result is very limited. An example for this are purchase proposals in large online shops based on customer segmentation, which change in general only rarely or marginally. A further influencing parameter is the number and type of source systems [46][47]. In order to cover a broad range of information, it may be advantageous to integrate several different source systems. However, from a critical point of view, problems emerge. The transmission from external sources can lead to delays. A further and currently very often-discussed topic is the veracity of information [48].

As already mentioned in section II, business processes must be adapted with regard to the newly gained flexibility and speed of data analysis in order to exploit the full potential [28][29][30]. The need for process adaptation has to be clarified on the base of the time business-value relationship concept from Hackathorn [45]. Figure 2 visualizes this concept and shows that the information-processing latency caused by IMIS can be reduced, but the additional business profit is relatively low. In order to generate a higher added value, it is also necessary to modify and accelerate the downstream decision-making and implementation processes.

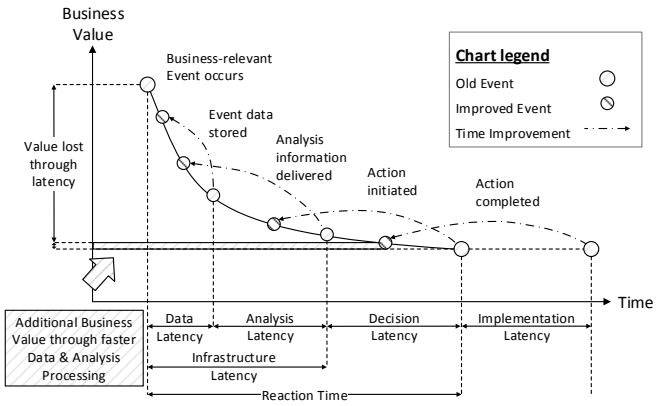

Figure 2. Correlation between time and business value (adapted according to [45])

B. Results of the expert survey

In order to evaluate the results and identify further influential factors, an expert study was conducted. One of the most frequent mentioned points in the interviews was the uncertain investment security. Despite the decline in hardware costs, the purchase of a main memory-based information system is associated with both high investment costs and a significant total cost of ownership [33]. As with any other investment decision, sufficient value must be generated to cover the cost of acquisition. A large proportion of the interviewed company representatives have criticized the poor cost-benefit ratio concerning IMIS and mentioned several reasons for that evaluation. In most business applications, mainly ”conventional” analyses and evaluations are carried out. These are already defined in advance or can be well predicted and scheduled. Due to the tactical or strategic character of the decisions, there is no exceptional urgency to obtain the results in most cases.

Apart from traditional OLAP tasks, the In-memory technology is perceived more positively. This includes, for example, the areas of predictive maintenance or the integration and analysis of social media. To implement a predictive maintenance, a large number of sensors must be integrated into the analytical system. The continuous measurement results in a high volume of data. Ideally, these data should be analysed as quickly as possible. Another example is the processing of social media, where large quantities of unstructured texts have to be processed. These two examples already confirm a significant proportion of the influencing factors from the first design phase. Another important criterion mentioned frequently were implementation conditions. According to the experts, not only the speed of decision-making is a relevant factor, but also the technical effort and legal obstacles that have to be considered. These factors were not taken into account in the previous literature. Efforts for the indoor localization or digital price tags were cited as examples for technical obstacles. An example for legal obstacles are the data privacy laws regarding the analysis of personal data, especially in EU countries like Germany, Spain or the Netherlands.

C. Conception and structuring of the framework

The literature review as well as the results from the expert study make clear that a variety of factors influence the assessment of IMIS scenarios. For a systematic analysis, it is necessary to structure the identified influencing factors.

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Figure 3 summarizes the results gathered from both the literature review and the expert study. Based on the results of the literature review, the factors can be clustered into two main categories: data and analysis factors. In the category analysis factors, a large part of the investigations dealt with questions of urgency, complexity or flexibility of analysis. Another segment of research focuses on data-driven factors. These include, among other issues, the volume, the topicality and the dynamics of data. As the hesitant spread of IMIS shows, the technical advantages alone are not enough to generate a substantial benefit. In the past research of IMIS, this fact was rarely taken into account. To consider aspects which are related to, e.g., real-time decisions and to take the results of our expert study into account, the categories were extended by the category of economic factors. This category contains factors with regard to internal as well as external implementation conditions, which are particularly important in the corporate context. The different characteristics of the factors show that some have a positive effect on the use of IMIS, while others have a negative impact. This means, e.g., that high requirements regarding the urgency of evaluations have a positive effect on the evaluation of an IMIS. To take this into account, we have added an influence indicator to our framework.

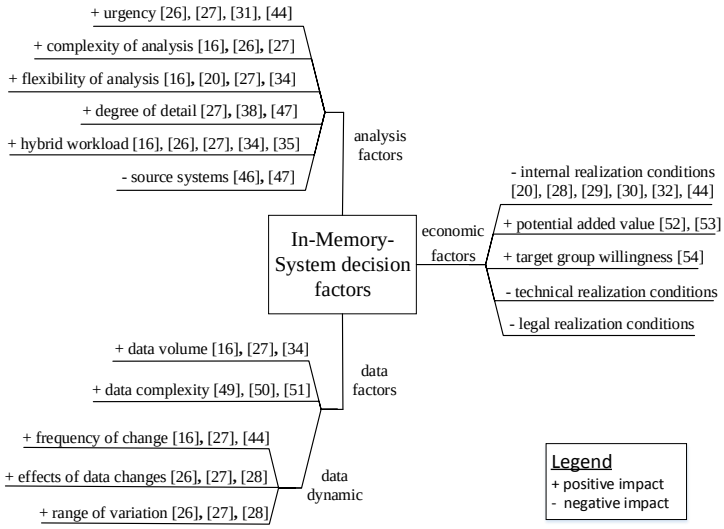

Figure 3. Overview of the analysis and evaluation framework

D. Application example of the framework

The functionality of the framework will be shown based on selected application examples from the retail sector. These examples were discussed during the expert interviews and in first case studies. For reasons of space, only the example ”analysis of sales and inventory data” [26] is explained in detail. For a better interpretation the results are summarized in the end.

1) Case study ”analysis of sales and inventory data”.: The goal of the ”analysis of sales and inventory data” [26] scenario is to discover anomalies in advertising and sales figures. High requirements are formulated regarding the urgency, the volume of data and the dynamics of the data of the IT system. The analysis of the information is mostly based on recurring standard reports. The complexity of the evaluation as well as the complexity of the underlying data in this case study is typically low. Sales documents in the retail sector are well-structured and can therefore be easily processed. A complex transformation is not necessary. All required data can be obtained from internal sources. Hence, there is no latency by loading data from external sources. Due to the high range of fluctuations in sales figures [55], the economic benefit of rapid intervention is quite high. At this point, the question arises which measures can be taken to minimize the fluctuations. In the work of Piller and Hagedorn, only non-price measures to reduce sales fluctuation are proposed [26]. In this case, there are no legal or technical obstacles to the realization of the measures. Evaluating the presented scenario characteristics it becomes clear that analytical requirements are on a high level and the data requirements are on a medium level. Due to the high economic benefits and low implementation obstacles, the overall potential for IMIS according to our framework is considered very high. In contrast to this, other examples show significant differences in the technical as well as the economic indicators.

2) Case study ”dynamic prices”.: For the example of dynamic prices [30], similar conditions apply as for the first scenario. From a technical perspective, the determination of dynamic and customer-specific prices is hardly a problem for current IT systems. In order to deploy a price differentiation, further prerequisites must be fulfilled. The information when a customer enters the shop and where he is located has to be available [56]. From a technical point of view, the challenge is to locate the customer exactly on several floors. Another fundamental requirement is the customers willingness to pay that individual price [54]. Reports about the introduction of individual discounts by a German retail company for example, led to extensive criticism and reluctance of the customers [57].

3) Evaluation of the case study results.: The evaluation of the attributes from a technical point of view implies the suitability of an IMIS for both use cases. The large data volume, the recently changing data, the need for quick responses and the combination of analytical and transactional tasks are strong indicators. The benefit of the presented framework becomes especially clear when the economic factors are considered. These factors indicate problems regarding the realization of the second example. With the help of the structured model shown in Fig.2, corporate decision makers can create a more holistic evaluation of potential use cases.

IV. Conclusion

The aim of this work was to create a framework for analyzing and evaluating application scenarios in the context of IMIS. As current research as well as statements from industry experts show, such a framework was missing. To cover all relevant factors for the application of an IMIS, not only theoretical work was included in this work. Through the inclusion of corporate experts, also practical aspects have been considered. Based on some of the first case studies in this area and scientific work, a large part of the influencing factors could be identified. Results show that the influence factors found through literature review and expert study could be divided into three main categories: analysis factors, data-driven factors and economic factors. Based on the expert survey, it was also possible to confirm the factors from the literature and to uncover other previously unconsidered factors. In order to take account of all aspects relevant to the companies, the model was

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expanded by features with regard to the profitability and the feasibility of possible fields of application. These include, for instance, the implementation conditions, legal obstacles or the willingness of target groups. Using the presented model, it is possible to examine potential and existing real-world scenarios regarding their requirements and their feasibility. In a next step, it will be necessary to evaluate the suitability of the framework based on quantitative investigations. To consider branch-specific variations of the relevance of the influence factors it is further useful to include corresponding weighting factors.

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