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Business value of in-memory technology – multiple-case study insights

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Abstract

Purpose – The purpose of this paper is to assess the business value of in-memory computing (IMC) technology by analyzing its organizational impact in different application scenarios.

Design/methodology/approach – This research applies a multiple-case study methodology analyzing five cases of IMC application scenarios in five large European industrial and service-sector companies.

Findings – Results show that IMC can deliver business value in various applications ranging from advanced analytic insights to support of real-time processes. This enables higher-level organizational advantages like data-driven decision making, superior transparency of operations, and experience with Big Data technology. The findings are summarized in a business value generation model which captures the business benefits along with preceding enabling changes in the organizational environment.

Practical implications – Results aid managers in identifying different application scenarios where IMC technology may generate value for their organizations from business and IT management perspectives. The research also sheds light on the socio-technical factors that influence the likelihood of success or failure of IMC initiatives.

Originality/value – This research is among the first to model the business value creation process of in-memory technology based on insights from multiple implemented applications in different industries.

Keywords Big Data, Business value, Case study, In-memory computing, In-memory data management

Paper type Case study

1. Introduction

A dominant theme in IS research is the quest for the business value contributed by information technology (IT). This topic has been addressed in numerous studies, from early contributions about the “productivity paradox” (Brynjolfsson, 1993; Pinsonneault and Rivard, 1998), which questioned the positive impact of IT on organizational performance altogether, to models proposing direct or indirect impact of IT on company performance (Weill, 1992; Soh and Markus, 1995; Tanriverdi, 2006), and to the stream of IT capability research (Bharadwaj, 2000; Liu *et al.*, 2010, 2013). Despite this knowledge base, there is still a need to deepen understanding about the exact way how

IT resources create business value, especially in interaction with other organizational resources such as processes and people (Melville *et al.*, 2004).

In-memory database technology, also called in-memory data management or in-memory computing (IMC) is a technology that received considerable attention in recent years. Its advocates anticipate a revolution for both business processes and enterprise data management because of higher database performance and diverse application fields. In-memory databases store data in main memory instead on disk, which enables faster data access than hard disk I/O (Gill, 2007). Combined with other database optimizations such as column storage and the associated data compression potential, IMC may support data-depending processes in ways impossible in the past.

Successful business applications of IMC are documented from areas like auto racing (Vizard, 2013), sales customer interactions in the manufacturing industry (Wust *et al.*, 2011), or financial reporting (Gill, 2007), albeit sometimes still in prototype status. These case descriptions report optimized organizational processes because of faster data processing and deeper insights into operations from flexible and fast analytics applications. What is missing is a systematic evaluation of the business value delivered by these IMC applications and the condition of the organizational context that enabled the implementations.

Academics and practitioners alike therefore face several questions: Does faster information processing help business processes in a significant way? Which departments or specific business areas should be targeted first to be supported by the new technology? Is IMC only enabler of very specific scenarios or will it have a positive impact on the entire IS architecture? Can it create competitive advantage for the company? Many studies have previously analyzed the value of IT in various applications, both with respect to market performance on firm level and operational efficiency on subordinate organizational levels. Bearing this research in mind, the aim of this paper is to learn about the business value of IMC by assessing the technology's organizational impact in different application scenarios. It addresses the following research questions:

RQ1. Which application scenarios can be identified where IMC delivers business value?

RQ2. How to analyze the organizational implications of IMC on a conceptual level?

A multiple-case study approach using data collected from five companies in different industries is used to answer these questions.

The reminder of the paper is organized as follows. Section 2 presents the existing literature about IMC and business value of IT. Section 3 introduces the research methodology with the case study approach. Section 4 describes and discusses the case evidence and presents the conceptual model. The final section summarizes contributions to research and practice.

2. Theoretical background

2.1 In-memory technology

IMC has first been described in database research publications in the 1980s (Garcia-Molina and Salem, 1992; Eich, 1988; DeWitt *et al.*, 1984). In-memory databases hold all or at least most of the data permanently in main memory instead on disk. The main advantage compared to conventional disk-based storage is the faster data access

speed due to eliminated time for disk I/O. Combined with a column-centric data storage layout that was introduced in the late 1990s, especially business intelligence (BI) applications benefit from higher query response times.

IMC has received increasing attention in recent years. Analyst company Gartner named it as one of the top ten strategic technology trends for 2013 (Gartner, 2013). The growing attention for this technology that has been available for three decades has two main reasons. First, all large database hardware vendors now have IMC solutions in their portfolio, which have become economically feasible for many companies due to dropping memory prices and 64-bit operating systems (Gill, 2007). Second, IMC is talked about as one solution for coping with “Big Data” challenges, a topic that is increasingly taken up from IS research (Chen *et al.*, 2012; Bharadwaj *et al.*, 2013; Baesens *et al.*, 2013).

The business value that can be provided by IMC has so far not been analyzed extensively. Besides technical research from the computer science domain (Harizopoulos *et al.*, 2008; Krueger *et al.*, 2010; Lu *et al.*, 2000; Bernstein *et al.*, 1998) current research on the topic can be divided into two streams. The first primarily considers the technological features and tries to deductively derive general business benefits from it. The second and smaller stream of research uses empirical insights from early adopters and technology vendors’ documentations to learn about valuable application scenarios in the broader organizational context and to inductively derive insights about its business value. The following paragraphs summarize findings from the two streams.

On one side, the business value from IMC is reported on a level that is still close to the technical features and focuses mainly on better data availability and its consequences. Six such characteristics related to data availability can be distinguished. The core benefit is seen in faster processing power, which benefits all kinds of processes needing quick data access and processing (Davenport and Snabe, 2011; Acker *et al.*, 2011; Lechtenbörger and Vossen, 2011). The second refers to greater flexibility in data access for users, which enables interactive queries (Davenport and Snabe, 2011; Plattner and Zeier, 2011). Third, information contained in the database is potentially more up to date and therefore presents a better basis for time-critical decisions (Plattner and Zeier, 2011; Piller and Hagedorn, 2012; Lehner, 2011) and fourthly it is consistently available on a more detailed level than before instead in aggregated format, allowing for “drill downs” to single data instances (Acker *et al.*, 2011; Piller and Hagedorn, 2012; Zeier *et al.*, 2011). Fifth, covering an aspect that is important more for IT departments than for business users, data models are simpler in in-memory databases compared to traditional relational databases, leading to simpler development and maintenance and eventually lower maintenance costs (Plattner and Zeier, 2011; Acker *et al.*, 2011). Finally, it is stated that due to these performance benefits the divide between transactional databases (also referred to as OLTP, online transactional processing) and dedicated databases or data marts for analytical purposes (OLAP, online analytical processing), which was created to optimize analytical queries in an environment separate from business-critical operational data processing, will become obsolete. This argument foresees the elimination of an entire stack of IT infrastructure that will lead to a simpler architecture and lower total cost of ownership (Plattner and Zeier, 2011; Schütte, 2012). A summary of these points is given Table I.

These benefits, however, are not systematically related to actual application scenarios in business processes, let alone to company performance indicators, which

reduces their explanatory power in the quest for IMC's business value contribution. Moreover, they are mainly deductively derived from theory and laboratory IMC technology tests with little empirical backing from field applications.

The second research stream analyzes the business value of IMC based on existing implementations or expert interviews with an explicit focus on the organizational context and implications for business processes. Our research identified only three relevant academic sources, all originating from German-speaking European countries. The first analyzes the impact of IMC on business processes in a BI context (Wessel *et al.*, 2013). They define three viewpoints on the impact on business processes, which are first evaluated against a literature review of current IMC research and second assessed by four BI experts. They find that decision processes are likely to be accelerated and that IMC is a valid tool for real-time BI. It is expected that this will lead to more "effective and efficient" business processes (Wessel *et al.*, 2013, p. 1791). The second source are two publications by Piller and Hagedorn (2011, 2012) who assess the potential applications and value of IMC in a retail context. They first develop a categorization of business process characteristics that can help identify processes benefiting from IMC support. They then apply these characteristics to a retail case to derive several potential process applications where IMC will be valuable. Finally, Vom Brocke *et al.* (2014) present a collaborative research project conducted with Hilti Corporation, an early adopter of IMC. They develop and evaluate possible application scenarios for the manufacturing company and use these insights to design a value creation model with first- and second-order effects for business value of IMC. In contrast to the research at hand, Vom Brocke *et al.* use a single-case study methodology and develop the model from several scenarios in planning stage.

Finally, not all studies are entirely supportive of the view that IMC will contribute significant business value. Skeptical voices do not question the technology's potential *per se*, but have doubts regarding the impact it will unfold for organizations. Stonebraker predicts that data will keep growing faster than storage will become cheaper, rendering IMC economically unfeasible as storage for all data and, thus, prohibiting division-spanning, company-wide scenarios (Stonebraker, 2011). Given this inconclusive and scarce knowledge base, there is a clear need to investigate this topic further.

2.2 IT business value

Determining the business value from IT investments and operations is an ongoing theme in the IS research community. Besides evaluations of the value of IT in

No.	Benefit	Authors
1	Faster data processing	Davenport and Snabe (2011), Acker <i>et al.</i> (2011), Lechtenböcker and Vossen (2011)
2	More flexible data access	Davenport and Snabe (2011), Plattner and Zeier (2011)
3	More up-to-date data	Plattner and Zeier (2011), Piller and Hagedorn (2012), Lehner (2011)
4	Less aggregates and deeper drill-down	Acker <i>et al.</i> (2011), Piller and Hagedorn (2012), Zeier <i>et al.</i> (2011)
5	Simpler data models	Plattner and Zeier (2011), Acker <i>et al.</i> (2011)
6	Convergence of OLAP and OLTP	Plattner and Zeier (2011), Schütte (2012)

Table I.
In-memory computing
benefits derived from
technical characteristics

general, researchers always seek better understanding of the value of specific technologies of their age. Examples are studies on the business value of Electronic Data Interchange in the late 1990s (Chatfield and Yetton, 2000; Mukhopadhyay *et al.*, 1996) or of radio frequency identification (RFID) in the 2000s (Tzeng *et al.*, 2008; Dutta *et al.*, 2007; Lee and Özer, 2007). Considering the current interest in IMC as novel technology of this decade, there is a clear case for analyzing its business value similar to established approaches.

The IT business value literature is theoretically grounded on the resource-based view (RBV). The RBV holds that organizational resources can provide competitive advantage if they are valuable, rare, hard to imitate or transfer, and non-substitutable by other resources (Conner, 1991; Barney, 1991; Mata *et al.*, 1995). Different methodological approaches are used to study business value creation based on the RBV. First, a traditional view close to the original RBV is to evaluate the competitive advantage of the firm (Mata *et al.*, 1995; Ross *et al.*, 1996). Difficulties in directly measuring the competitive advantage and the need for larger-scale empirical research made publicly available market performance and profitability indicators like market capitalization, sales, or profit ratios popular (Bharadwaj, 2000; Sircar *et al.*, 2000). Third, as alternative or complement measures, operational efficiency and productivity indicators such as capacity utilization or inventory turnover are considered (Weill, 1992; Barua *et al.*, 1995). Evidence for a positive relationship between IT and business value was found repeatedly in both older and more recent studies (Quan *et al.*, 2003; Dong *et al.*, 2009; Wang *et al.*, 2012; Hitt and Brynjolfsson, 1996), although some mixed evaluations exist (Chae *et al.*, 2014). Divergent findings are sometimes attributed to differences in level of analysis (individual or organization-level) and research measures (qualitative or quantitative) (Chan, 2000).

Most studies agree that the profitability or productivity contribution of IT does not directly follow from IT investments and technology adoption, but from its positive impact on organizational processes and structures, which in turn influence firm performance (Barua *et al.*, 1995; Melville *et al.*, 2004; Soh and Markus, 1995). Despite the general consensus that a potential positive effect of IT exists, there is still a need for a better understanding of the underlying mechanisms and organizational conditions moderating it (Ravichandran and Lertwongsatien, 2005; Melville *et al.*, 2004). This paper adopts the same view of IT as enabler of intermediate benefits and proposes a model that captures the intermediate benefits of IMC that will eventually contribute to firm value.

Conceptual multi-stages models are established instruments for visualizing the indirect link between IT and firm value. Some existing models take an explicit business process perspective assuming that IT impacts business processes execution which in turn influences organizational performance in the affected area and on firm level (Bakos, 1987; Melville *et al.*, 2004; Peppard *et al.*, 2007; Vom Brocke *et al.*, 2014). Using the theory of organizational capabilities (Bharadwaj *et al.*, 1999; Bhatt and Grover, 2005), others view competences and capabilities that follow from IT resources as the linking construct to firm performance (Bharadwaj, 2000; Ravichandran and Lertwongsatien, 2005; Wang *et al.*, 2012). Hardly any contribution explicitly considers the organizational changes necessary to generate value from IT. In view of the novelty of the IMC technology, it is critical to regard process changes necessary for implementation as these may outweigh the advantages.

Summarizing, hardly any research contribution has so far assessed practical IMC application examples and tried to derive a general model of business value of IMC.

3. Research methodology

The aim of this research is to understand concrete IMC applications and their situational contexts in which IMC generates business value. The relationship between technological characteristics and value drivers will be captured in a conceptual model. This research applies a qualitative case study methodology which is considered appropriate for studies of contemporary phenomena to explore subject matters in rich, real-life organizational contexts (Yin, 2013). In contrast to most quantitative studies with a firm-level unit of analysis, the chosen qualitative approach studies IMC applications at a lower organizational level in their specific business process contexts for two reasons. First, even early IMC early adopters can at most report on a few years of experience with the technology. Second, also due to limited technology maturity, IMC initiatives are currently mainly implemented in specific company areas or processes. Hence IMC initiatives do not yet affect firm-level performance indicators but can be expected to cause observable effects in the respective organizational areas. Moreover, Barua *et al.* (1995) argue that IT implementation effectiveness may differ across applications within a single company, sometimes rendering firm-level analyses less insightful.

Of the existing conceptual models for business value of IT reviewed in Section 2, only one takes technology-specific process changes explicitly into account (Peppard *et al.*, 2007). Building on Peppard *et al.* (2007) as well as on Melville *et al.* (2004) and Vom Brocke *et al.* (2014), the model developed here consists of the five elements drivers, IMC enabler, realization conditions, business benefits, and contribution to company goals (see Figure 1). This model allows capturing the full organizational context of an IMC implementation in line with the logic of existing multi-stage models.

This research applies a multiple-case study design that permits more controlled observations and deductions, cross-case comparison, and better robustness and generalizability compared to single case studies (Lee, 1989; Darke *et al.*, 1998; Yin, 2013). Multiple-case designs depend on careful case selection to maximize insights from the study (Dubé and Paré, 2003). Eisenhardt (1989, p. 537) suggests theoretical sampling of “extreme situations or polar types” for best insights on the process under investigation and recommends four to ten cases as a reasonable number. In line with this advice, this research chose five companies from different industries who had all completed “proof-of-concept” (PoC) pilot implementations or ran completed IMC implementations. Of those five, three initiatives were operational, whereas the other two had decided against an actual implementation after PoC completion. The original sample included ten companies, but since half of them were still in ongoing “proof-of-concept” stages, only five companies with completed pilots were chosen to ensure a more reliable state of facts.

Figure 1.
Conceptual in-memory
computing business value
creation model

Data were collected by interviews based on a semi-structure interview guideline in the second half of 2013. The interview guideline covered all elements of the conceptual model (see Appendix). Depending on the project organization in the different companies, the authors conducted interviews with one to three project team representatives, whenever possible from both IT and business departments (see Appendix). The authors took extensive notes during the interviews and completed them within 24 hours which can substitute tape-recording when diligently done (Darke *et al.*, 1998). To enhance case study evidence validity and reliability, the study adhered to the following data collection principles from Yin (Yin, 2013). First, this research considered multiple sources of evidence, which allows for triangulation. Next to the interviews, interview partners provided internal project documentation material. Second, all collected information from the cases was pooled in a single case study database. The authors then created individual case study reports that were handed to all interview partners to ensure correctness of facts, which complies with the advice for qualitative data analysis to ensure within-case understanding before moving to cross-case analysis (Miles and Huberman, 1994). Table II summarizes the five cases' basic facts. The cross-case analysis by means of a meta-matrix (see Section 4) allowed the creation of the conceptual model for IMC business value creation.

4. Research results and analysis

4.1 Case descriptions

E&ECo is a large international engineering and electronics company. The company operates a central department responsible for master data quality supporting both business and IT functions with a consistent and accurate view on E&ECo's core business objects. To prevent the creation of duplicate and wrong human resource (HR) records in case of relocations or new recruiting in one of the many global HR departments, E&ECo needs a high-performing search and duplicate check solution that can run against its central HR master data database. Lacking such a solution in its current IT architecture, E&ECo implemented an IMC database alongside its current database to enable fast and precise fuzzy searches on name and address data records. The solution is operational since end of 2012 and is valuable for E&ECo's global HR departments.

ChemCo is a specialty chemicals company with international production sites. IMC satisfies ChemCo's analytic demands regarding dynamic margin simulation for its global operations. The solution can calculate the effects of varying transfer prices

No.	Company designation	Industry	In-memory computing application scenario	Project completion status
1	E&ECo	Engineering/ electronics	HR master data quality management	Operational
2	ChemCo	Chemicals	Margin simulation management dashboard	Operational
3	RetailCo	Retail	Inventory and personnel management	Partly operational
4	EnerCo	Electric utility/ energy	Global HR Shared Service Center	PoC completed, project abandoned
5	RailCo	Transportation	Predictive equipment maintenance	PoC completed, project abandoned

Table II.
Overview of in-memory
computing cases

between business units (BUs) on BU margins, enables alternative views (central and BU) on these margins, and offers dynamic simulations with changing parameter values for raw material prices. Moreover, the IMC solution includes a management dashboard that gives access on corporate-wide financial data featuring complete drill-down to individual records and fast response times. The implementation uses backend and frontend from different IT solutions vendors.

RetailCo is a European retailer with food, non-food, and service sector store formats in its core market. Despite RFID tags and barcode scanning in warehouses and at cash outs, RetailCo incurs stock-outs due to deviations between actual and system inventory levels on super market shelves. To reduce the need for costly manual stock level checks in supermarket shelves by point-of-sales personnel after closing time, RetailCo successfully conducted an IMC proof-of-concept project for enabling real-time checks of stock levels in retail shops that can be executed during opening hours. Following the favorable PoC, the backend for the solution has been developed, and project go-live in test stores is planned for 2015.

EnerCo is an European power and gas company. As part of EnerCo's strategy to more efficiently support its global operations, the company evaluated the implementation of a new Shared Service Center for global HR based on an IMC database. Goals of the new solution were improved system response times, improved system scalability, and new functionalities like real-time analyses of open service tickets. In the PoC, EnerCo valued global system user feedback and technical performance tests positively, but decided against an implementation because projected acquisition and implementation costs were found to outweigh the expected benefits.

RailCo is a European railway and transportation company. It conducted a PoC to evaluate an IMC solution for solving performance issues and missing functionalities of current transactional and analytical reporting systems. One scenario targeted a predictive maintenance capability for RailCo's infrastructure management. If data on rail network performance and disturbances were available and analyzed in real time, insights could be gained for more effective maintenance activities for vulnerable network areas. RailCo could however not convincingly prove the business value so that the IMC initiative was not pursued further.

4.2 In-memory technology business value model

One core insight from the case studies is the fact that the technical advantages of IMC can indeed lead to business value in various applications across industries, albeit not always in a measurable monetary way, which answers the first research question. The business value generation process (cf. Melville *et al.*, 2004) however depends on organizational transformation and business process changes paving the way for the benefits.

With regard to *RQ2*, a conceptual model should explicitly include these organizational structures and processes to reflect the conditions for value creation. The model developed here with its five elements (Drivers, IMC Enablers, Realization Conditions, Business Benefits, and Contribution to Company Goals) proved effective in collecting evidence on the IMC business value relationship in the five cases. Table III presents the cases' core characteristics with respect to these elements in a conceptually ordered meta-matrix (cf. Miles and Huberman, 1994). Although many organizational change aspects are idiosyncratic by nature, the cross-case analysis reveals that some commonalities are attributable to IMC technology across companies. In the following,

Table III.
Cross-case comparison

	E&E Co	ChemCo	RetailCo	EnerCo	RailCo
Drivers	Missing fuzzy search functionality on HR master data Poor validation and duplicate check functionality IMC database side-by-side to HR database	Insufficient reporting flexibility Heterogeneous local reporting workarounds Competitive pressure	Costly manual stock level checks after closing time Missing real-time capability of current system IMC database side-by-side inventory mgmt. database	Insufficient performance of current HR Shared Service Center (SSC) and missing functionality Vendor strategy	Data loading times into data warehouse too long Insufficient reporting flexibility
IMC IT Enabler	Check dependencies and prepare (e.g. update) other IT infrastructure components Search algorithm development Renegotiate contracts with suppliers	IMC database as business warehouse with separate frontend Cross-functional teams with global involvement for tool selection Develop new data models Redesign IT department's billing process to internal customers	Adapt current architecture to allow for real-time data flow Develop new data models Change operative process for new checks during opening hours	IMC database side-by-side HR database of SSC Create "business readiness" with employee training for new functionality and cross-functional teams Renegotiate contracts with suppliers	IMC database as business warehouse Check dependencies and prepare (e.g. update) other IT infrastructure components Redevelop access rights policies Employee training on new functionality
Benefits	Real-time access and duplicate check on worldwide HR master data records Higher employee satisfaction Global HR support	Insightful and flexible management dashboard Corporate-wide margin reporting and simulation in real time Easier to maintain data models	Lower personnel costs from saved overtime payments Higher inventory level accuracy in systems Improved inventory and order management	Higher employee satisfaction from faster query response times Daily SSC ticket completion with view on full employee history Scalable SSC IT infrastructure	Lower change mgmt. costs in IT with shorter report development times Faster data availability for predictive maintenance application
Contribution to strategic goals	Increased work efficiency for global HR departments Collection of experience with new Big Data technology	Harmonized IT reporting solutions landscape Ability for data-driven decision making in fast-changing environment	Higher transparency over operations Collection of experience with real-time scenarios	Collection of experience with new Big Data technology	Higher transparency over operations Ability for data-driven decision making

the common characteristics of the five elements are described and finally summarized in Figure 2.

Drivers: drivers capture the motivations why the companies began dealing with IMC in the first place. The two most important drivers for IMC evaluation projects found in the case studies were insufficient performance of current systems (in transactional or analytical use cases) or altogether missing functionalities. Besides those internal drivers, external factors like software vendor influence (most notably, SAP's strategy with their in-memory database HANA) and competitive pressure were mentioned.

IMC IT enabler: the IMC solutions in the five cases are enabler for different business scenarios. The cases differed with respect to database size and technical implementation. Whereas E&EC_o, RetailCo, and EnerCo used replicated "side-by-side" implementations next to their conventional databases, ChemCo and RailCo used an IMC database to replace current data warehouse databases. Independent of the exact deployment solution, IMC offers the primary technical advantage of very fast data processing of large data sets.

Realization conditions (IT and business): some realization conditions stand out as influencers whether the business and process benefits can be efficiently realized. They can be distinguished into organizational and process-related aspects and system-related aspects to highlight the respective organizational responsibility. On the organizational and process side, important conditions were cross-functional teams, user training, and process redesign. Depending on the implementation, redesigns ranged from training on new system features to new guidelines for decision-making processes. On the system-related side, the main enabler for IMC is new data modeling and an end-to-end evaluation and – where necessary – refinement of the IT architecture to realize the data processing speed improvement from IMC.

Benefits (IT and business): given the realization conditions, IMC can lead to higher user satisfaction because of faster data processing and ultimately to deeper company insights in case of analytical applications (ChemCo, RailCo). In transactional applications, it can also lead to time and cost savings in "near real-time" cases (RailCo). On the IT benefit side, the new data models are found to be easier to maintain and the architecture to be scalable.

Contribution to strategic goals: the frequently used "organizational performance" category is approximated here by "contribution to strategic goals". This accounts for the fact that the observed applications do not yet deliver measurable performance benefits but mainly intangible benefits. The interviewed project managers almost unanimously mentioned the three goals "data-supported decision making", "360° view on operations" and "collection of experience with "Big Data technology".

Figure 2 shows the aggregated view on these elements with the IMC business value generation model.

4.3 Discussion

The case study findings and the new model extend the current knowledge on in-memory value creation. In relation to Vom Brocke *et al.*'s (2014) "four general principles of value creation through in-memory technology", this research confirms the first principle that IMC provides first-order and second-order effects, where the first-order effects are related to the technical features such as fast processing of large data sets (confirmation of principle 3). In contrast, the second principle that the second-order effects manifest in "advanced business analytics" and the "convergence of OLTP and

Figure 2.
In-memory computing
business value
creation model

OLAP" (Vom Brocke *et al.*, 2014, p. 159) is only partly confirmed in this study. At the current technology maturity level, a convergence of OLTP and OLAP cannot be observed because companies do not yet use IMC technology to replace entire legacy systems for transactional and analytical purposes but instead create additional structures alongside current systems. This puts a damper on high-flying hopes for IT infrastructure savings from IMC in the near future, especially considering the still comparatively high costs for large IMC databases. In addition to Vom Brocke *et al.*'s findings and the literature, other second-order benefits manifesting in the IT organization are the better scalability of IMC structures and the better data model maintainability, which are important in light of permanently growing data volumes.

This study adds rich insights to Vom Brocke *et al.*'s fourth principle that value creation is restricted by "the capabilities of the overall socio-technical structures and processes" (Vom Brocke *et al.*, 2014, p. 161). The cases clearly show that the faster data processing capability of IMC does not directly lead to better organizational performance but depends on both original project drivers as well as conditions during project execution. Based on the analysis of the three implemented and two abandoned cases after PoCs, these factors can be summarized in a list of critical success factors and barriers to IMC implementation projects. Success hereby refers to implemented IMC projects where decision makers were convinced the value would outweigh costs. Barriers hereby reflect cases where arguments against an implementation at worst led to project abandonment. Table IV presents the findings.

This research suggests that besides the second-order benefits mentioned above, IMC as an IS resource may contribute to higher-level capabilities such as data-driven decision making and superior business understanding ("360° view on operations"). In view of growing requirements to quickly respond to changing market environments, which necessitates fast and reliable data availability for decision making, IMC can thus generate business value even without immediate positive return on investment for a specific application scenario.

5. Conclusion

Although in-memory databases were first described more than three decades ago, it is only now that sinking hardware costs make widespread use of this technology economically viable. Previous research in computer science and the IS community has mainly emphasized its technological advantages over conventional database systems

Barriers	Success factors
IMC project is planned as mere infrastructure upgrade under pressure of calculating a positive business case	IMC project is driven by specific business need that cannot be supported with current means
IMC application targets a business process where the pain of slow data processing is not critical enough	IMC application targets a business process where "time is money" (time as direct cost driver) so that the value of data processing velocity is obvious
Strong technology skepticism and unrealistic expectations among decision maker	IMC project is backed by top-management or corporate IT strategy
IMC implementation neglects optimization of in- and outbound data flows to the in-memory database, failing to reap the technology's full potential	IMC implementation considers end-to-end data flows across all affected systems for the planned application and systems ancillary to in-memory database are adapted if necessary

Table IV.
Observed barriers and
success factors to IMC
implementations

and focused less on business scenarios where the technology could generate value. This research addresses this gap by analyzing five cases of IMC applications in different industries. It sheds light upon the drivers for the technology, organizational change conditions, and the resulting business benefits.

This research contributes to the knowledge about IMC as a novel technology that has so far received little attention in the IS research community. It develops further the research on business value of IT and derives a conceptual model to capture the IMC business value creation process. This research considers the organizational contexts and necessary change requirements to successfully implement this technology. Further research could empirically analyze the main drivers, implementation conditions, and business process benefits identified in this exploratory study to determine which factors are the most relevant one. This would help to assess the technology's future value and likely dissemination. Another relevant research topic would be to analyze the impact of the IMC project team composition on the project result.

The study offers three main contributions to practice. Firstly, the study may help shaping managerial expectations regarding IMC value in different applications. Whereas (near-) real-time business process and analytics support could be observed in the study, the often-touted convergence of OLAP and OLTP was not realized in the observed cases and is believed to occur only in the medium- to long-term when the technology is more mature. Second, the findings show that managers could use the popular "3 V's" Big Data definition (Russom, 2011) to identify valuable applications scenarios: business processes that require extraordinary velocity ("real time" processes), feature extreme data volumes, or a greater variety of data may be interesting candidates for IMC applications. Finally, the study sheds light on some of the success factors and barriers for IMC implementations.

A limitation of this study is its focus on only five companies that were all in very early stages of IMC implementations. Implementation effects have therefore not yet diffused widely into the organization, which would allow for using more objective measures of the business value. Future research could look at more mature cases to assess IMC's business value. Another limitation is that with one exception all companies in the sample used in-memory solutions from the same vendor (SAP's HANA). Future research could test if this study's results apply to IMC in general rather than to the specific manifestation. Moreover, future research could look into other new data storage technologies such as solid-state disks and study their business value impact in comparison to IMC.

Findings suggest that the power of IMC lies in the breadth of applications that can be supported in various company areas. IMC can thus be expected to diffuse into many organizations' IT architectures in the near future, where it will be worthwhile to be analyzed regarding aspects such as integration into existing architectures, monetary value contributions, and new valuable application scenarios.

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Appendix. Interview partners and sample questions from interview guideline

No.	Company designation	Interviewees from case company	No. of interviews (duration)	Supplementary company material ^a
1	E&ECo	Senior Systems Engineer	2 interviews (of 1 h and 1.5 h)	Yes
2	ChemCo	Head of Central Reporting Systems	2 interviews (of 1.5 h)	Yes
3	RetailCo	Head of BI Development	2 interviews (of 1.5 h)	Yes
4	EnerCo	Central Business Processes Architect, Application Manager	2 interviews (of 1 h and 2 h)	Yes
5	RailCo	Business Project Manager, Senior Software Engineer, Head of BI Management	3 interviews (two of 1.5 h, one of 1 h)	Yes

Notes: ^aSupplementary material included internal project documentation documents like planning and final report presentations, meeting protocols, business case calculations, and technical descriptions. Details may not be disclosed for confidentiality reasons

Table AI.
Interview partners

Sample questions from interview guideline

1. Background
 - 1.1 Please introduce yourself: name, department, position in the company, and experience in the company.
 - 1.2 What is/was your role in the project?
2. Project triggers
 - 2.1 When did awareness for the technology arise in your company?
 - 2.2 What were internal and external drivers to start the project?
 - 2.3 Who took the decision to implement the project and who led the implementation?
3. Project description
 - 3.1 Please describe the IMC application scenario in detail: targeted business process(es), affected people and department(s), data sources.
 - 3.2 Did you consider multiple scenarios?
 - 3.3 How was/were the scenario(s) evaluated?
 - 3.4 What is your previous and new IT architecture?
4. Project goals
 - 4.1 What was the overall goal or vision of the IMC application?
 - 4.2 Which specific advantages did you expect to realize? From a business perspective and from an IT perspective?
 - 4.3 Which goals were realized and how were they measured?
5. Project realization conditions
 - 5.1 Which changes were necessary to implement the solution? Which was the most critical one?
 - 5.2 Did you encounter challenges?
6. In-memory computing in your company and in general
 - 6.1 How do you assess the general significance of IMC for your company and your industry? Why?

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