REAL-TIME OR NEAR REAL-TIME? - TOWARDS A REAL-TIME ASSESSMENT MODEL

Completed Research Paper

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Abstract

Since the advent of information technology, the availability of up-to-date information has been a key goal. Recently the term “real-time” has been discussed in combination with technologies such as in-memory-computing. However, the promoted acceleration of data availability and response times are accompanied by high investment costs to implement such infrastructures. Businesses are faced with the question of whether the increased real-time capability actually translates into benefits beyond pure up-to-date availability. This paper argues that the additional value for the business is essential and proposes a model for assessing and classifying business processes’ real-time level. It aims to assess the information requirement of specific processes and determines the suitable level of data availability. It shows that real-time information is not always required and investments in real-time infrastructures may represent an over-investment. A case study from the automotive industry illustrates the model and presents some early implications for the usability in practice.

Keywords: real-time, assessment model, in-memory computing, business value
Introduction and Problem Statement

The quality of decision making processes strongly depends on the quality of the available information. This applies in particular to competitive and dynamic environments, which are the reality in many of today's industries (Poess and Nambiar 2010). To improve the quality of decision making a quick and profound analysis of operational processes needs to be combined with faster data processing (Jörg and Dessloch 2010). However, we find that data retrieval, data analysis and the presentation of information are still often dissociated from the operational process execution (Janiesch et al. 2011). In dynamic environments a higher frequency (several times a day) of the availability of current control-relevant information is necessary to adapt to intraday changes of customer needs, capacity constraints, exchange rates and the like. Closely linked to this basic mechanism known from systems dynamics (or cybernetics) is the term “real-time”. Real-time support – implemented by dedicated information technology (IT) systems - should enable the availability of information in real-time, shorter response times, the use of simulations and new production concepts.

Providing information faster was also the guiding idea behind the Enterprise Resource Planning (ERP) system SAP R/3. In view of the planning complexities present in most businesses which involve a match of demands and capacities, ERP systems based on the manufacturing resource planning (MRP2) principle often required hours to complete the planning runs, which led to new information for decision making. To improve this situation, ERP providers have been pursuing the idea of making the entire ERP available in a high-performance in-memory infrastructure. In consequence, the term “real-time” has also been discussed in combination with in-memory computing (Pezzini et al. 2012). Current solutions of different IT vendors, e.g. SAP with HANA (Plattner and Zeier 2011) or Oracle with the Exalytics In-Memory Machine (Murthy and Goel 2011) are among the examples. According to statements by these companies, an acceleration of data access by a factor of 1000 to 2000 can be achieved by modern in-memory systems and response times may be reduced to a few seconds (Plattner and Zeier 2011). However, there are very high investment costs to implement such an infrastructure. Hence, it is relevant to assess how much real-time information business processes actually need so that costs and benefits are proportionate. Sigg (2012) describes some examples for today’s in-memory solutions but it lacks reliable studies (Loos et al. 2011).

Regardless of the chosen architecture, transformation of existing business processes based on real-time infrastructure as well as an economic analysis for their use have only been addressed in literature while both research and praxis consider this an essential aspect. The use case is crucial to assess the benefit of the pointed progressions. Depending on the case, the need for real-time data fluctuates (Loos et al. 2011). Thus, considering the additional value of a real-time infrastructure is essential. While data update cycles of seconds may be necessary in some processes, in other cases data updates within minutes or hours are sufficient. Taking into account that the real aim should be faster decision making and not only speeding up information, faster systems and real-time data availability per se do not ensure real-time processing. Therefore, real-time requirements have to be reflected regarding the supported process (Hackathorn 2004). According to Davenport and Snabe “the real question when it comes to information delivery is how fast and flexibly to do it, so that what ultimately gets faster and smarter is not the information supply, but the decision making that determines a business’s performance.” (Davenport and Snabe 2011).

Concerning the addressed aspects the main research question pursued in this paper is whether a certain real-time IT-infrastructure is a relevant technology development for business processes. It presents a business-driven perspective and a real-time assessment model that - based on the real-time requirements of a process - provides insights about the meaningfulness of investments in real-time infrastructures.

Research Approach and Methodology

The research process is based on the Design Science approach (Peffers 2007). After defining the research objectives, an assessment model (artefact) was developed based on prior research as well as requirements from practice. The paper follows the hypothesis that each business process configuration has specific information requirements and that a level of real-time support for a business process (“real-time level”) exists. It is the goal of the artefact to determine whether the current IT-infrastructure suffices to support the identified real-time level, as well as to assess whether investments in a real-time infrastructure are profitable (Business/IT alignment). From a practical perspective, decision makers may use the model to
support strategic investment decisions.

The development of a real-time assessment model is depicted in the following sections. After analysing the concept of real-time in previous developments, the derivation of indicators to determine a business process' real-time level from different application areas is described. The indicators were gathered from literature and from findings extracted from five interviews with practitioners in industrial companies. The partners were chosen considering a spread range of their respective scope (head of IT, supply chain executive, head of production planning, software producer and specialist). These interviews contributed identifying and distinguishing the different needs of business processes regarding real-time support. Based on the interviews and the extended literature review, indicators were developed to classify the identified real-time levels, as well as their value per level. Afterwards the model is constructed and the insights derived from it are described. To design this model well-established approaches were used, e.g. for considering the business value. A case study from the automotive industry serves to present a first evaluation of the model and some early implications for the usability in practice.

The Concept of “Real-Time” and Real-Time Enterprises

The concept of real-time computing has already been discussed in previous literature and provides a basis for analysing real-time from a technological as well as from a business perspective.

Terminological Basics

The real-time concept may be viewed from different perspectives. In the field of computer science, “real-time” refers to dialogue/real-time processing in which processing user requests occurs without significant delay and users get immediate feedback on their queries (in distinction to batch-mode computing) (Martin 1965). In contrast to a non real-time system that does not guarantee a response time in any situation, real-time response times are determined within a predefined time interval of (milli-) seconds (hard definition). In the discipline of information systems (IS), the term real-time is associated with the objective of full networking and real-time integration of the functional areas of a business. Integrated data processing across all areas of business enables automating tasks, reducing manual routine tasks, increasing productivity of labour input and processes previously impossible (Lee et al. 2008).

Hence, a real-time enterprise has specific characteristics. One is the integration of internal and external data in the respective data management-infrastructure in real time. In addition to real-time data integration and delivery, also analyses on this data may occur across functions and at any time in real time. Slow and inflexible information delivery may lead to gaps of information and major business problems in some areas, e.g. in production, when a supplier is unable to deliver a special material just-in-time or just-in-sequence. In a supply chain, both processes are demanded on behalf of manufacturers and thus critical for suppliers. A real-time business is characterised by interactive processing (e.g. interactive analyses or simulations) of the user, instead of exclusive work on out-dated data as is usual in batch processes. Typical fields for faster processing are for example supplier management in the automotive industry or collection and analysis of real purchasing behaviour in the commercial sector (Kuhlin and Thielmann 2005). Thus, companies have to implement an infrastructure which supports fast decision making in those areas based on substantiated information. Often management based on a linkage between historical analytical data and up-to-date transaction data is seen as the best decision source.

In the past businesses have already discussed and implemented infrastructures to support real-time data, such as ERP systems as a kind of transactional systems and infrastructures, such as real-time data warehouses (operational BI) as a type of analytical systems. In order to identify indicators that assist in determining a process’ real-time level, an analysis of these previous real-time approaches is presented (area of analytical and transactional systems) in the following.

Real-Time in Enterprise Resource Planning Systems

The real-time paradigm has been discussed for decades in the field of ERP systems – a term coined by the Gartner Group in the early 1990s (Jacobs and Weston 2007). ERP systems are computer-based systems that support cross-functional processes using a centralised database that integrates all information flowing through an enterprise (Davenport 1998). By integrating a wide range of functions of an enterprise – such as customer supply chain, sales, production and finance etc. - the user should get universal, real-
time access to current operating data anywhere and anytime. Real-time information is used e.g. to connect different departments in a company, such as sales and production planning. The system automatically updates related information when someone enters new information in an operating system (Davenport 1998). The design of an ERP system needs to fulfill objectives, such as the reduction of data redundancy, standardization of the interface and various business practices or the elimination of conflicting information (Jacobs and Weston 2007). “Today more than ever, the capability of such systems to allow additional decision support and information analysis packages to be “bolted on” has become another critical feature” (Jacobs and Weston 2007).

Implementing the system appropriately may yield significant improvements regarding efficiency, productivity and service quality that in turn may lead to a reduction in service costs (Ngai et al. 2008). However the execution of ERP plans often comprises multiple hours. “Consequently, interactive analyses, planning runs or simulations are in many cases not possible.” (Piller and Hagedorn 2011). To deal with this problem today’s IS are separated in two parts: a database system rendering the data management and a system containing the application logic such as an ERP system (Loos et al. 2011).

In contrast to the ERP systems, which belongs to the OLTP (online transactional processing) systems (operational systems), decision support for management is realized by analytical IS (today known as Business Intelligence (BI) systems). Data in OLTP systems are mostly transaction-based and reflect a recent level of information that is refreshed dynamically over time. Central dispositive data management systems (data warehouse (DWH)) are used in addition to ERP systems to make the data available for analysis systems (Plattner and Zeier 2011). Kimball clarified this by defining a DWH as “... a copy of transaction data specially structured for querying and reporting” (Kimball and Ross 2002).

Real-Time in Business Intelligence Systems

According to Kimball, the focus of a DWH is data analysis. Thus, the traditional DWH was designed for management, concerning just a few users (Kimball and Ross 2010). By using historical data (one day or older) previous BI systems only allowed a retrospective view of the facts and were not suitable for real-time use. Up-to-date transaction data remains in operational systems and is loaded into regular batch runs into the DWH (Farooq and Sarwar 2010).

In literature, the trend towards the integration of BI with the operational processes is conducted as operational business intelligence (opBI) or even real-time BI. Here BI tools are used to support operational and tactical tasks – coincident with the integration of the transaction systems into existing BI infrastructure (Eckerson 2007). Initial developments to real-time BI commenced at the end of the 1980s (Agrawal 2009). In the next years, the DWH-architecture was enhanced by Inmon (1996) and Kimball (Kimball and Ross 2002). The real-time data, which is needed for opBI, should be kept in an operational data store (ODS) (Inmon 1999). In the context of web-based commercial enterprises and the increasing flood of data (e.g. Big Data), BI became more relevant (Agrawal 2009). In recent years both practice and scientific approaches have been designed to provide data from the operational systems for real-time analytics and real-time control (Agrawal 2009), (Bruckner et al. 2002), (Farooq and Sarwar 2010). Although capturing all sorts of data nowadays is easier and storing them is cheap, real-time data analysis and actions are still supported insufficiently because of failing timeliness and quality of data in previous DWH solutions (Azvine et al. 2005).

Real-Time Processing and In-Memory Computing

A recent trend driven by technology is In-Memory Computing, which should enable real-time decision support. Thus, e.g. it can be considered as one possible enabler for opBI systems. The approach of the main memory database technology, in which all data from a database are kept and processed in the main memory, dates back to the mid-eighties (Garcia-Molina and Salem 1992). In the context of currently available low-cost hardware, that approach has recently gained new importance. The concept is seen as a basis for overcoming the previous separation between analytical (planning and control systems) and operational IS (Plattner and Zeier 2011). The adoption of in-memory computing facilitates solving problems or removing pain points (e.g. customer segmentation) and also the creation of new values with new applications (e.g. planning and simulation) (Sigg 2012).

Research on in-memory and real-time operating systems primarily focused on technical issues of data
processing and architectural changes (Lehner and Piller 2011; Plattner and Zeier 2011) as well as various business issues of the typical BI surrounding. Thus, e.g. Fabian and Günther (Loos et al. 2011) as well as Winter et al. (Loos et al. 2011) consider applications in the area of analytical BI. Yet based on current knowledge, in-memory solutions are especially lacking in applications. The technological potential still provides no convincing application benefit. Even if, according to the argumentation of IT-companies, large benefits (performance gains, cost reductions, increased agility as well as associated competitive advantages) can be generated using real-time technologies such as in-memory computing, the processes have to be real-time-capable. Until now there has been a lack of fundamental consideration of the costs for implementing or maintaining such a real-time infrastructure and the resulting benefits. Only if these are in proportion to each other, can sustainable improvements for the company be achieved.

Towards a Real-Time Assessment Model

Identification of Indicators to Determine Processes’ Real-Time Level

In order to develop a model for assessing and distinguishing business processes’ real-time levels, as well as to receive insights about the appropriate supporting IS infrastructure (e.g. value for business processes) as a first step a content conceptual delimitation of the different real-time levels (real-time, near real-time or non real-time) has to be conducted and generic real-time characteristics of business processes have to be identified. In previous publications we did not find comprehensive definitions for the classification of business processes in that area. To obtain indicators and their values for that classification, different fields of interest for the real-time paradigm and the assessment of IS infrastructures were analysed (in interviews and in literature). The results and derivations are presented in the following sections. All indicators and their values specified below are summarised in Table 2 (page 7). For illustrating the respective relation there are content links to the table in brackets within the text.

Real-Time Criteria Regarding Latency Aspects

Latency (delay time between an action and reaction) is one central consideration for dealing with the business value of real-time information, discussed e.g. by Hackathorn (2004) in the context of opBI. To clarify the relationship between time and business value, he drew a value-time curve (cf. Figure 1). Starting with an event, occurring within a process, data has to be extracted from the transactional systems, allocated and the information has to be analysed by a user before a decision is taken (Hackathorn 2004).

There are different types of latency. Data latency describes the loss of time between the creation of data by a business transaction and the availability of this data in the DWH (or another data management structure). The delay between initiating an analysis and delivering it to the relevant user is called analysis latency. Decision latency refers to the time between the user understanding the information and taking an appropriate decision based on that (Hackathorn 2004). The increasing demand for real-time processes requires a reduction in latency. Thus, the requirements on latency are crucial factors for determining a process’ real-time level. Adopting these arguments, the following indicators have been defined: time horizon till analysis results are relevant (cf. Table 2, 6)); time to action regarding restrictions in process control (decision latency) (cf. Table 2, 7)); data latency is separated into two parts: data freshness/time to data integration in the DWH after creation in the operational systems (cf. Table 2, a)); capability of response regarding data availability (cf. Table 2, b)). The analysis latency is presented by the response time (cf. Table 2, c)).
Real-Time Criteria of ERP Systems

Some design criteria for real-time implementation can be derived from the requirements for an ERP system. These systems have to support real-time access for up-to-date data (Davenport 1998). Hence, both the data timeliness (cf. Table 2, a)) and low response times for user queries (cf. Table 2, c)) are essential real-time design criteria for ERP systems. With the features of the ERP, management may analyse data in real time, in finer granularity and in multiple dimensions (Sia et al. 2002). The availability of suitable and timely data will create higher flexibility and an improvement in decision making. Furthermore, real-time information may lead to increases in efficiency and a reduction of process times. Additionally, the real-time capabilities of ERP systems allow competitive advantages by enabling new business processes, e.g. sales and operation planning that is connecting sales with production planning and scheduling. In this process the system automatically changes production schedules based on customer orders (Davenport 1998).

In ERP systems all generated data is not confined to any functional boundaries (various users, multiple purposes, at several places). To exchange data, individual modules of an ERP system have to be synchronized with each other. While early systems only worked with mainframe computers, nowadays client-server technologies and scalable relational databases are used. Therefore high scalability of the data model (cf. Table 2, f)) is also required for real-time processing (Gupta 2000). A key requirement for ERP is performance. Early versions of ERP systems - material requirements planning and master production scheduling – are neither fast enough nor scalable enough for today's requirements, but they still exist in many companies. To update them to a faster and more dynamic structure, the advanced planning and scheduling (APS) engine was created, which synchronizes both systems. With faster background engines like APS response times should be reduced significantly and better business results will be enabled (Gupta 2000). Contrary to the requirements, Piller and Hagedorn (2011) declare that response times for elaborate computations in current ERP systems can still amount to several minutes. This makes interactive (Szuprowicz 1995) analyses, planning runs or simulations impossible (cf. Table 2, 5)). They mention the use of in-memory data management as one possible technical solution to eliminate these problems.

Real-Time Criteria of DWH-Architecture and In-Memory Computing

BI requires a DWH as well as analytical and reporting tools. The challenge for real-time BI is accessing data that is extracted from ODS with zero latency and forwarding actions into business processes in real-time (Azvine et al. 2005). The challenges for BI are data integration (ETL-process) and incremental maintenance. Indicators for ETL technologies are (1) data volumes, (2) frequency, (3) latency and (4) mode (Farooq and Sarwar 2010). Depending on the implementation of the DWH architecture, there is a classification of the DWH and in consequence also of BI. As shown in Table 1 the ETL can be sub-divided in a real-time, near real-time and traditional type. That sub-division has been adapted for defining the three real-time levels in this research (cf. Table 2, header).

<table>
<thead>
<tr>
<th>Table 1. Classification of Loading Processes (cf. Farooq and Sarwar 2010 and Kotopoulos 2012)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ETL-Types</strong></td>
</tr>
<tr>
<td><strong>Mode</strong></td>
</tr>
<tr>
<td><strong>Description</strong></td>
</tr>
<tr>
<td><strong>Frequency</strong></td>
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<tr>
<td><strong>Data Volumes</strong></td>
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<tr>
<td><strong>Latency</strong></td>
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<tr>
<td><strong>Capture</strong></td>
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<tr>
<td><strong>Initialization</strong></td>
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<tr>
<td><strong>Target Load</strong></td>
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<tr>
<td><strong>Source Load</strong></td>
</tr>
</tbody>
</table>

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Compared to traditional ETL processing with batch-mode update cycles of more than one day (cf. Table 2, a, b) the challenges in near real-time or real-time are shorter update intervals (Jörg and Dressloch 2010). Thus, the frequency fluctuates from minutes to daily updates for near real-time and from seconds to minutes for real-time processing (cf. Table 2, a, b)). Also latency can be reduced when the decision process is automated. The persistence layer is changed. The traditional ETL process is enhanced by ETL with a direct data feed (ETL DDF) and ETL with real-time data caches (ETL-RDC) (Farooq and Sarwar 2010) or Change-Data-Capture-ETL (CDC-ETL) (Kotopoulis 2012). CDC-ETL includes techniques for detecting changes, e.g. timestamp- or trigger-based method (Thiele and Lehner 2010). “The real-time aspect in the context of DWHs describes a new processing model where every change is automatically captured and pushed into the DWH.” (Thiele and Lehner 2010). Most of studies, e.g. Plattner and Zeier (2011) or Thiele and Lehner (2010), discuss the meaning of real-time based on the criterion of data freshness (cf. Table 2, a)) and data availability (cf. Table 2, b)) in a DWH (area of databases).

In-memory computing enables processing large data sets, which, inter alia, can be dragged directly from operational systems in real time. The first applications of these new technological potentials were found to increase the performance of existing BI solutions (analytical field). Due to the availability of all business data in real time, large volumes of data (cf. Table 2, d)) can be analyzed at runtime and from any perspective (Plattner and Zeier 2011). To handle enormous amounts of data, it is necessary to adapt the applications. Most applications were implemented 20 years ago meaning that they are not generally designed for scalability. Most of the database structures are not designed for scalability either (Sigg 2012). But with the in-memory technology, applications will be distributed to expandable memory or CPUs. Today, conscious data structures and highly parallel algorithms (cf. Table 2, i)) are needed to measure the real-time requirements (Sigg 2012). Real-time data acquisition is performed on a push-driven approach to ensure a continuous capture and delivery of current data between the source system and the DWH (Pareek 2010). Various potentials are arising from using such technologies that load data into main memory and distribute it by scaling to multiple CPUs. Analysing information in real-time at unprecedented speeds in large volumes (cf. Table 2, d)) of non-aggregated data (cf. Table 2, 8)), creates flexible analytic models based on real-time and historic business data (spectrum of data, cf. Table 2, e)), founds new application categories (vom Brocke 2013) and minimizes data duplication (Sigg 2012). In-memory technology also enables efficiency gains in IT departments such as hardware cost reductions by simplifying the architecture or reduced external memory requirements (Plattner and Zeier 2011).

**Workflow-Related Indicators**

In addition to the technology aspect, the processes also have to be considered by the real-time approach. Some business processes may be suitable for a real-time decision support, others not. Hence, in addition to indicators resulting from IT-requirements, there are also some specific workflow measures affecting the real-time level. It is quite conceivable that certain restrictions in processes (e.g. based on dependencies on other (sub)-processes or political requirements) mean that e.g. accelerated availability of data is of no use.

According to Piller and Hagedorn (2011), business processes that have the following properties are particularly suitable for real-time support: (I) high level of dynamic data, (II) high range of variation of information (level of fluctuation and corresponding influence on corporate success), (III) high number of analysis options and working hypotheses, (IV) urgently needed results (e.g. during meetings) (V) high complexity of analysis, (VI) large data volumes. In reverse a further six superior indicators associated to these values were defined in that research: (1) frequency of information changes in processes (cf. Table 2, 2)); (2) range of information change (cf. Table 2, 3)); (3) number of action and process options (cf. Table 2, 1)); (4) urgency of simulation or analysis results (cf. Table 2, 6)); (5) complexity of analysis (cf. Table 2, 4)) and (6) grade of data aggregation (cf. Table 2, 8)). The last point also influences the data volume. Using detailed transactional data generally causes a higher amount of data than data aggregated in Key Performance Indicators (KPI) (cf. Table 2, d)).

Business Process Management occurs as a collection of tools and methods for managing and improving a business network’s process portfolio. To provide business process analytics in a timely manner, ETL jobs are needed several times a day and not – as before - a batch process overnight (cf. Table 2, 5), 6), a), b)). It is necessary to expose information, which is needed, more than once a day (cf. Table 2, 2), 7)) (Janiesch et al. 2011). In current industrial practice, real-time KPI is presented to the user through dashboards by BPM, which allow more accurate decisions at any point of time (Solomon and Litoiu 2011).
Construction of a Real-Time Assessment Model

In the following a comprehensive assessment model is proposed by combining and adapting prior model approaches. After a summary of the previous deflected real-time level indicators, the portfolio analysis as an instrument for strategic decisions as well as parts of a well-established measurement model of IS success are used as the basis for designing such an assessment model.

Adapting Indicators from Prior Research

Based on the analysis in the previous sections three possible real-time levels for business processes are suggested: (1) the process is non real-time (traditional batch process), (2) it is a near real-time process (updated data within minutes to hours available; intraday control) or (3) the process is real-time capable. To distinguish and characterise these levels, 14 indicators have been derived from the insights. These are separated into two dimensions. On one side, there are indicators affected by the workflow (workflow-related characteristics). The second dimension is formed by indicators describing the data and system conditions (characteristics of IS infrastructure). The following table sums up all analysis results:

<table>
<thead>
<tr>
<th>ID</th>
<th>Indicator</th>
<th>Real-time</th>
<th>Near real-time</th>
<th>Non real-time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Number of action and process options</td>
<td>many</td>
<td>medium to many</td>
<td>a few or none</td>
</tr>
<tr>
<td>2</td>
<td>Frequency of information changes in process (data dynamics)</td>
<td>frequent</td>
<td>frequent changes</td>
<td>rare changes</td>
</tr>
<tr>
<td>3</td>
<td>Range of information change (and impact on business)</td>
<td>high</td>
<td>medium to high</td>
<td>small</td>
</tr>
<tr>
<td>4</td>
<td>Complexity of analysis based on provided data (intensity of calculations for processing)</td>
<td>high, extensive evaluations</td>
<td>low to medium, simple evaluations</td>
<td>low, simple evaluations</td>
</tr>
<tr>
<td>5</td>
<td>Type of (data/KPI) analysis in process (flexibility)</td>
<td>interactive</td>
<td>interactive (limited) and not interactive</td>
<td>not interactive</td>
</tr>
<tr>
<td>6</td>
<td>Time horizon until analyses results are relevant (organizational latency)</td>
<td>seconds to minutes (data is urgent)</td>
<td>several minutes</td>
<td>hours to days (less urgent)</td>
</tr>
<tr>
<td>7</td>
<td>Time to action regarding restrictions in process control (decision latency)</td>
<td>immediately to several minutes</td>
<td>hours to days</td>
<td>days, weeks, months, years</td>
</tr>
<tr>
<td>8</td>
<td>Grade of data aggregation</td>
<td>low (detailed, transactional data)</td>
<td>low to high grade</td>
<td>data high aggregated (KPI)</td>
</tr>
<tr>
<td>a)</td>
<td>Timeliness / time to integration of data in the data management structure (DMS) after entering the operational systems (infrastructure latency I)</td>
<td>real-time update immediately after creation</td>
<td>update DMS as frequently as possible (Active DWH)</td>
<td>periodic batch run - daily, weekly or even monthly basis</td>
</tr>
<tr>
<td>b)</td>
<td>Capability of response regarding data availability (infrastructure latency II)</td>
<td>a few seconds</td>
<td>a few minutes</td>
<td>&gt; one day</td>
</tr>
<tr>
<td>c)</td>
<td>Response time of DMS for user queries</td>
<td>a few seconds</td>
<td>several minutes</td>
<td>several hours</td>
</tr>
<tr>
<td>d)</td>
<td>Supported processible data volume at runtime</td>
<td>high</td>
<td>medium to high</td>
<td>small</td>
</tr>
<tr>
<td>e)</td>
<td>Spectrum of data</td>
<td>historical and/or current data</td>
<td>historical and/or current data</td>
<td>historical data</td>
</tr>
<tr>
<td>f)</td>
<td>Scalability</td>
<td>high</td>
<td>medium to high</td>
<td>low</td>
</tr>
</tbody>
</table>
Using these classification criteria, an assessment of the as-is process in terms of its real-time level is possible. The review should be taken by experts from practice because they know both their processes and the need for data supply. As it can be assumed that an unambiguous assignment is often difficult – i.e., each classification criterion would result in the same real-time level – process profiles are formed to assure more differentiation. The same method is taken for classifying the to-be process, thus, all deltas between the as-is and the to-be process are derivable (cf. Figure 2). To define the to-be process, the economic outcomes of the company/the business unit are taken as a basis. From a strategic perspective, e.g., the following targets in production exist: (1) high adherence to delivery dates, (2) high capacity utilization and productivity, (3) short processing times, (4) low inventory level, (5) high robustness, (6) high flexibility, (7) low costs (Khanna 2007). If an enterprise changes its strategy or the economic objectives have not been met to a sufficient extent, associated processes are directly affected because the strategic objectives have to be implemented in the processes (vom Brocke and Rosemann 2010). To achieve their objectives, firstly the features of the process have to be adapted in the right form.

A classification in a portfolio matrix is considered appropriate for a graphic representation of the real-time level of a company’s processes and as a basis for strategic decisions (e.g., investments in IS).

Adapting the Portfolio Analysis Approach

Portfolio analysis is an important tool in strategic planning. Portfolio models serve to illustrate and characterize strategic alternatives and directions. Complex interactions of business and market are reduced to a two-dimensional matrix, representing current and future situations (Turnbull 1989). Based on the original concept different models have been formed for various questions, e.g., market growth/market share portfolio (four-field matrix of BCG), market attractiveness/competitive strength portfolio (nine-field matrix of McKinsey) or the technology portfolio (Turnbull 1989). In addition to the initial approaches, there is now a variety of options and the concept has been expanded into other potential fields. The idea of presenting decision problems in the form of a two-dimensional matrix analog is used for many problems based on difficult quantifiable criteria.

For presenting the issue discussed in this paper – an assessment of business processes’ real-time level regarding the organisational and IS infrastructure as well as assessing the value of a real-time infrastructure - a matrix approach seems reasonable. In accordance to the two dimensions developed in the previous section the matrix shown in Figure 3 arises from the consideration of the workflow-based specification (measurement “workflow”) and the specification of IS infrastructures (measurement “IS”). Business processes are positioned in the portfolio matrix with respect to these two parameters and thus, they can be evaluated and prioritized. Hence, a process-portfolio is developed. Using the portfolio-based representation helps a business to see clearly which level their current processes are at, which direction they want to point them into and which kind of changes (workflow or IS-based) are useful regarding a balanced relationship between the two dimensions. According to the nine fields of the McKinsey matrix, the axis divisions “low”, “medium” and “high” are applied in this research regarding the aspect of real-time levels. Hence, the classification “low” is adapted for the “non real-time” level (cf. Figure 3: Non RT), “medium” for “near real-time” (Near RT) and “high” for “real-time” (RT).
The dimensions are a result of the aggregation of the different indicator values described before (distinction between indicators, that describe the procedural characteristics and requirements as well as those that describe the properties of IS): The outcome of executing the procedure to assess the real-time level (Figure 2) is a predefined score value (e.g. 1 = non RT, 2 = near RT, 3 = RT) for each indicator. By using a scoring method, a metric was formed from the single indicator values. Therefore one value between 0 and 1 is formed per each of the two dimensional axes as the bottom line, whereby an exact intersection point in the matrix is obtained. If the value of one indicator changes, the point shifts accordingly in the grid towards another real-time level. In order to create a balance between the levels on the two axes, processes should ideally be located in the areas of the central diagonal (dark grey boxes). These boxes show the match between IS and workflow. In case of sliding upward, but not to the right of the matrix, an infrastructural deficit will arise: the process has real-time requirements, however the infrastructure does not support that. On the other hand, sliding to the right, but not upwards implies that the there is a process deficit regarding the available infrastructure.

**Adapting the Model of IS Success**

Measuring what makes an IS successful is seen as an important factor in science and practice to determine the value of IS investments. Hence, a lot of measurement models have been developed. However, only a few of them could be established within the last years. The model of DeLone and McLean as well as the Technology Acceptance Model (TAM) are seen as the dominating measurement models in literature and have been adapted and validated by many researchers (Dörr et al. 2013). TAM is based on principles of social research and creates statements about the use or disuse of a system by users. That model is unsuitable regarding the focus of this research because we act on the assumption that all information provided by the system at the right time definitely creates value to the process or user. Thus, a disuse of an IS generally occurs as a result of a time deficit of information supply.

DeLone and McLean (1992) postulated a comprehensive and multi-dimensional measuring model of IS success. Due to its prevalence, the generic applicability and the intersections with our research, this model was chosen as a source to generate a comprehensive overview of the developed assessment model (cf. Figure 4). A system has various properties that determine its success. McLean and DeLone reviewed existing diversified definitions of IS success including their corresponding measures to provide a general definition that covers various perspectives of evaluating IS (DeLone and McLean 1992). Ten years after the publication of their first model and based on the evaluation of many inputs, they proposed an updated IS success model. In that they divided measurements of IS into six interrelated dimensions of success: information quality, system quality, service quality, (intention to) use, user satisfaction, and net benefits (DeLone and McLean 2003). Due to these dimensions, the following categories and key measures have been identified as relevant factors influencing the real-time level of a business process:

- system and information quality: timeliness, data currency, response time (cf. Table 2, a), b), c))
- (information) use: Based on workflow characteristics there are interdependencies to indicators relating to the measures: frequency of requests and access (cf. Table 2, 1), 2), 6), 7)), actual vs. reported use and report acceptance (cf. Table 2, 3), 5), 6), 8)), type of information used (cf. Table 2, 4), 5), 8)).

Every process and every decision maker in the workflow has specific requirements regarding the timeliness, the frequency and the speed of information for decision support as well as the response times of a system. As described, this results in the process’ real-time level. Referring to the elements of the portfolio approach mentioned in the section before these requirements are represented by the “workflow” dimension. In comparison to the model of DeLone and McLean that part corresponds to the “intention to use” dimension and finally affects the level of “use” of an IS (Figure 4, box a)). An appropriate IS that aims to ensure this provision of information is successful if it is able to meet these requirements accordingly (match between workflow and system). It has to provide the right information at the right and prescribed time to decision makers to satisfy them. The capabilities of IS are described within the dimensions of “system quality” and “information quality” in the model of DeLone and McLean. As the aspect time with the link to the provision of information are crucial for this research paper, only those measures of the DeLone and McLean model are relevant that fit into these categories. Referring again to the elements of the portfolio matrix, the character of the IS is presented by the dimension “IS” which is a combination of both indicators that describe the system as well as the information quality (Figure 4, box b)). Adequate quality of data preparation and usefulness of the information provided as a suitable basis for decision
making is presumed. Thus, the dimension “service quality” is negligible.

“User satisfaction” (Figure 4, box c)) is determined by the level of fulfillment of the mentioned requirements by the system. A user is satisfied in the case of entire or exceeded customer fulfillment. In the portfolio matrix this match (workflow and system) is presented by the marked intersection point. To determine the actual value of an IS regarding the supported process’ real-time level, the “Net Benefit” of the DeLone und McLean model is assumed as an additional element to our research (Figure 4, box d)). A positive Net Benefit arises if the user is satisfied and uses the system (DeLone and McLean 2003). In addition to the benefit referring to the system use itself (stakeholder: IT department) the benefit for the business process and the whole company is also considered in this research (stakeholder: process owner and company).

The following case study from the automotive industry illustrates the proposed model and presents some early implications for the usability in practice.

**Case Study from the Automotive Industry**

Based on the developed model in the previous chapter a case of component manufacturing regarding its real-time level in the scheduling process is analysed in the following. Furthermore, the IS infrastructure is considered and the process is checked for benefits regarding a real-time IS infrastructure.

The case deals with the production of components used by an automotive manufacturer, which occurs as a sequence of production ("just in sequence" (JIS)). The enterprise has several plants in Germany and worldwide but special components (e.g. engines, gearboxes, steering shafts) are only produced in one factory in Germany. Components are delivered from this plant (producer’s plant (PP)) just-in-time to other plants (customer’s plant (CP)). Due to that delivery, the CP does not have storage area for these materials. Thus, a delayed material delivery (production slows down), as well as a delivery that arrives too early (material transporter has to wait in front of the plant) creates problems. Fast and flexible adjustments of scheduling in the PP as a reaction to changing frame conditions in the CP are imperative to guarantee the material supply for the JIS process.

Regarding these challenges, the right IS infrastructure that meets the process information requirements and supports the decision maker in an adequate manner has to be determined. A real-time architecture is seen as one possible solution. But how much real-time is useful in that process? Applying the developed model (Figure 4) helps to define the right type of architecture regarding the business value. The results are listed in detail in the next sections.

**Assessing the Real-Time Level of the Business Processes**

In the following, the process characteristics of the scenario are analysed in detail and they are classified based on the developed indicators (cf. Table 2). Consequently the level of real-time support required by the IS is determined (cf. Figure 4, box a)). Furthermore, as described in the assessment model, these requirements are opposed to the functionality of the current IT infrastructure (cf. Table 2 & Figure 4, box b)) in the “Characteristics of IS” section. The assigned real-time values for each indicator, separated by workflow and IS, are summarized in Figure 6. To illustrate the respective relation there are content links in brackets to the single indicators in Figure 6 within the following statement.
Workflow Characteristics and Requirements

In the best cases, a CP reports the delivery time as well as a number of units (components) required on the specified date to the PP. The PP assigns these units into their sequence chain and ensures that the delivery is feasible to the CP at the scheduled time. In case of production problems in the CP, discrepancies of the reported target goods may occur and as a consequence the agreed delivery schedule will change. If the CP moves the original agreed delivery schedule, the PP has to respond by adapting the delivery sequence. Only in this way can the PP ensure that the orders of the highest urgency are handled next and potential bottlenecks can be avoided. With the data and KPI provided, the process owner (planner) controls his delivery quality in terms of delivery reliability to the CP. The "security of supply" is the most important KPI on which his performance is measured. That indicates the quality of material supply.

The time period between the initially reported date and the relevant requested date thereafter may reach up to one day. This time buffer can be positive (CP needs the components earlier than planned) or negative. A positive time buffer may be accumulated over several weeks, while a negative time buffer may occur within a few hours. Missing components in production cause vehicles to be removed from the line and at worst threatens a line standstill (cf. Figure 5). These consequences are in turn associated with significant additional costs (conversions, resource idling etc.).

![Figure 5. As-Is Process (Upper Illustration) and To-Be Process (Lower Illustration)](image_url)

Process data in the CPs (e.g. order execution time, cycle time = effective daily operating time/required daily quantity of output (Monden 2012), number of finished items) generally change several times a day. Thus, data in the as-is process as well as in the future are characterized by high dynamics and frequent changes. The data required originates from 10 to 12 different source systems of the PP and CPs. Some of these are directly connected to the CPs production. The data contained therein are changed when triggered by events in second-intervals (at least in cycle time, which is less than one minute). Another part of the source systems is connected to the logistic systems. Coupled to the order reference of the delivery systems. Coupled to the order reference of the delivery systems they receive current information if the shipment status changes. These data are changed at minute to hour intervals (< four hours). Opposed to many of the operational data, aggregated KPIs and the delivery time do not change by the second either, which is why the model indicator “frequency of changes” is assigned as near real-time (cf. Figure 6, 2)). Due to the heterogeneity of the source systems, the extraction of data as well as the KPI calculation is a complex process. Until now they are based on a data entry that is
enforced manually twice a day to shorten update cycles. Despite the data preparation, the “complexity of analysis based on provided data” regarding the required system processing is expected to only be mediocre (cf. Figure 6, 4)). Although the planner uses a lot of single information to reschedule, he merely conducts simple evaluations based on IS use. With regard to the existing IS infrastructure and the associated high manual effort such analyses are not even practicable in the as-is process (non real-time, cf. Figure 6, 4)).

For a quick response and adequate rescheduling the planner needs about 30 single items of information per analysis procedure (e.g. agreed schedule of delivery, last covered agreed schedule of delivery, daily material needed, last order sent to PP, time lag between planned and current production schedule, cycle time, number of items ordered). This information is partially required in a kind of calculated aggregated control parameters (e.g. a percentage value for “security of supply”). The volume of data to be handled is only about 10-20 MB and negligible in view of specific requirements for the architecture. Due to the initial processing of operational details and a few aggregated KPIs, the process is also determined by near real-time characteristics for the indicator “number of action and process options” (cf. Figure 6, 5)).

Because of frequent data changes in the CP, the timeliness of the information cycles of 10-15 minutes are considered necessary on the part of the PP to respond quickly to any changes and to ensure the security of supplies for the CP. In consideration of a “time horizon until analysis results are relevant” of about several minutes this workflow requires a near real-time infrastructure (cf. Figure 6, 6)). Indeed current IS infrastructure does not provide the cockpit with required data and KPI to the PP to analyse the situation in the CP sufficiently. Latencies are too high. IS provides data only once a day (cf. next section for details). Due to this and the resulting time-consuming manual steps to collect and prepare necessary data, the management of the as-is process is significantly restricted and a near real-time control is impossible. Thus, an uncertainty occurs in the JIS process. Most of the information needed cannot be provided in the right time frame. Hence, shifts in production are noticed too late to react in a flexible and quick manner.

After receipt of the current information, the PP planner is able to reschedule the order sequences or quantities within a few minutes as needed. However, the average manufacturing time of the components takes about two hours. Once the manufacturing process has been started, a rescheduling is not possible. In addition, there are transport times to the CP. Thus, lead times of six to seven hours are necessary (approximately one shift) and the “time to action regarding restrictions in process control” is several hours (cf. Figure 6, 7)). Scheduling and rescheduling in the PP as a response to changes follows a two-stage procedure. Firstly, the planner manually determines the premises of rescheduling (e.g. production sequence) and what changes are executed. In the second step a tool automatically generates new production plans based on these specifications. Software-supported simulations of various scenarios are not used and are not considered necessary in the to-be process. Hence, the planner’s level of interactivity (Szuprowicz 1995) with the IS is low (push functionality) and is classified as non-real-time taking into account the corresponding model indicator “type of analysis in process” (cf. Figure 6, 5)).

Several alternatives are possible to adjust the production planning. In general, the planner has two main lines of action responding to changes: modification of the order sequence or adjustment of the production output. These two alternatives in turn are sub-divided to a variety of partial alternatives (e.g. division of delivery quantity in several parts, distribution to an alternative CP (completely or in parts), to bring the production forward (completely or in parts) etc.). It is also possible to store a small proportion temporarily as another decision option. Regarding the lack of data support of current IS, responsiveness is limited and thus, the “number of action and process options” of the as-is process amounts to only a few options. Supporting the planner with the required data at the right time increases the range to approximately 20 sub-alternatives. Compared to other workflows in that domain (manufacturing in the automotive sector) this was evaluated as a medium number of options by the experts (cf. Figure 6, 1)).

The average “security of supply” is 98% in the current process. In case of availability of intraday data and the faster responses to changes, the quality of the material supply may be significantly increased. According to expert estimates, the average “security of supply” increases to more than 99% if current data is available every 10-15 minutes. Furthermore, the specialist division expects that the use of a new IS architecture, which satisfies the corresponding process requirements, creates an absolute monetary benefit in the amount of € 35,000 per year at the PP. This mainly results due to the reduction of inventories and the better resource utilization. The values of the control KPIs mentioned above depend on various factors. As described, a fault in the JIS process has far-reaching effects for a CP and thus, also
influences the company's success. However, various escalation mechanisms are implemented in business because of the sensitivity of the production processes. Hence, such failures are compensated for to a certain degree and are normally reversed over the time by various measures, e.g. by additional shifts. For this reason, the “range of information change” is assessed as medium to high (cf. Figure 6, 3)).

Characteristics of IS

As already clarified in the previous section, the current IS infrastructure does not provide the data and KPI required to analyse the situation in the CPs sufficiently to the PP. Latencies are too high. The data required to supply the process with the necessary information is currently time-consuming as it is manually extracted from the operational systems. This is based on the prevailing nightly batch cycles of the existing IS infrastructure (cf. Figure 6, a)). IS provides data only once a day (cf. Figure 6, b)). Outdated data (only historical “spectrum of data”) that is available for analyses the next day is insufficient for operational process control (cf. Figure 6, e)) because of modified conditions and plans occurring in the meantime in the CPs. There is no need to save the data used over longer periods either. Hence, the classical DWH structures that are used to provide historical KPI generate no significant benefits in this scenario. The data is consolidated from different systems of the CPs and the PP. Calculations of the mentioned KPI are very complex and until now they are based on a data entry that is enforced manually twice a day to shorten update cycles. Hence, a near real-time or real-time control is restricted so that an uncertainty occurs in the JIS process.

“Timeliness” and the time to “data availability” have to improve. Taking the requirements of reducing further inventories at the PP into account and of increasing number of JIS orders means that the timely provision of data becomes even more significant. Production line and management require a timely creation of data to respond to failures and to initiate changes. According to the PP decision makers, timeliness and the availability of the information cycles of 10-15 minutes (cf. Figure 6, a) + b)) are considered necessary to respond quickly to any changes and to ensure the security of supplies for the CP. Bottlenecks in delivery, problems with storage and production stops have to be avoided in the future process by near real-time updates. In addition, a reduction of tied-up resources (e.g. stocks, transport vehicles) as well as an increase in capacity utilisation of resources (e.g. production machines, packet size) will be possible. Currently the “processable data volume” supported by the existing IS infrastructure is low at runtime (cf. Figure 6, d)). Although data volume is negligible in this case the requested near real-time architecture automatically provides a higher processible data volume at runtime.

Due to the use case characteristics, indicators c) and f) are insignificant and were not considered in the evaluation. Figure 6 summarises the findings of the analysis relating to the real-time level of the process:

![Figure 6. Use Case Real-Time Level (As-Is, To-Be)](image)

Taking the current process requirements into account most of the indicators in the to-be process have a near real-time characteristic. This has a high relevance regarding the non real-time characteristics of the existing IT infrastructure.
Creating the Process Portfolio Matrix

To illustrate the match between the real-time level of the workflow and the IS (workflow support: Figure 4, box c) the portfolio-based representation is used. This matrix helps to assess the balance between the two dimensions “workflow” and “IS” for the use case analysed in the case study. The dimensions of the deviated matrix below (Figure 8) are a result of the aggregation of the different indicator values deduced in the previous sections. For each indicator value a predefined score value (1 = non RT, 2 = near RT, 3 = RT) has been assigned. The results are summarized in Figure 7.

By using a scoring method, a metric has been formed out of the single indicator values for both the workflow and the IS dimension. The outcomes of this are four values: as-is workflow = 0.31; as-is IS = 0; to-be workflow = 0.44; to-be IS = 0.5. At the bottom line two exact intersection points are obtained: x = (0.31; 0) and y = (0.44; 0.5). Intersection point x represents the as-is process, which is restricted by the current IS limitations. The process requires near real-time data supply but the infrastructure does not support that. Thus, an infrastructural deficit occurs in the current process and the user is dissatisfied (Figure 4, box c)). As a consequence the Net Benefit for both the system use and in terms of the company’s benefit is negative (Figure 4, box d)). Statements about this benefit derived from the case study analyses have a primarily qualitative character. Realising a procedure to determine the quantitative benefit is part of our further research.

To receive a balanced relationship between the two dimensions, the company has to enhance the IS into a near real-time infrastructure. In the matrix this appears through intersection point y: The to-be process requires a near real-time IS infrastructure to support the workflow characteristics.

By enhancing the IS, manual efforts can be avoided in the future and workflow restrictions resulting from the insufficient information supply will be eliminated. With a data timeliness and availability every 10-15 minutes, a shift of process data will be evident for the PP and they quickly recognize whether the CPs require the ordered components before or possibly after the original deadline. The planner is able to react timely by rescheduling and bottlenecks in the CP are omitted. Hence, the JIS orders improve.

To realise such an infrastructure, a change of the existing ETL process is required among other things (resorting to CDC near real-time ETL). Hence, the adaption of the IT infrastructure is essential for the improvement of the process, which does not achieve near real-time criteria in the as-is process because it is not able to handle near real-time data. A redesign of the architecture ought to guarantee this. Saving the near real-time data e.g. in the DWH or an ODS, enterprise-wide access to relevant information is possible within a few minutes.

As a first awareness from this use case, it was found that a near real-time support is sufficient for this process. Even with highest update rates, e.g. the process flow is not able to schedule to the split second. Thus, a real-time infrastructure does not generate additional value. A shift of the IS dimension towards real-time would require higher investment costs for the architecture. It contrasts higher costs with
corresponding benefits for further reducing latency. The PP has to commission the manufacturing of the components. Fast responses after shifts in the production are desirable, but an analysis of the data at second intervals is not necessary. The use of an in-memory solution is conceivable in this case. The period of data updates every 10-15 minutes is sufficient so that it is possible to build the architecture by enhancing existing IT components.

**Discussion and Conclusion**

This paper proposes a model for the assessment and classification of business processes’ real-time level. It aims to assess the information requirement of specific processes and determines the suitable level of data availability. In addition, the model intends to review whether the current IT infrastructure suffices to support the identified real-time level as well as to assess whether investments in a real-time infrastructure are profitable (Business/IT alignment). From a practical perspective the real-time assessment model may be an additional instrument for strategic investment decisions on new technology.

In the context of the topic of real-time content in the workflow and in the IS, it is shown that both aspects need to be considered to make significant statements about the classification of the real-time level and the infrastructure required to support that level. As already suggested by Mani (Mani et al. 2006) for the case of business process governance both dimensions need to be aligned. Assigning the research of Henderson and Venkatraman, this is described as the alignment between business and IT as well as the alignment of their strategies (Henderson and Venkatraman 1993). Both factors, IS and workflow, have to be determined separately and matched (balanced configuration). Implementing a near real-time process, for example, also assumes a near real-time infrastructure. Otherwise there is a functional deficit (or on the contrary an over-investment). The impact on business (business value) is crucial.

As an additional contribution this paper illustrates that real-time is a differentiated concept that comprises multiple real-time levels. Besides the highest form of "pure real-time", a broad spectrum of near-time exists that satisfies many business needs (e.g. since many supply chains do not fully react in real-time, but are pre-scheduled). In addition some non real-time business processes exist.

The in-depth case of the automotive industry illustrates the assessment model and presents some early implications for the practical usability. By adapting the model, a classification of the real-time level of the as-is and to-be processes was possible. This use case has shown that the necessity of real-time has to be discussed for each process. More real-time is not always the solution. Business requirements (and benefits) need to drive technological investments. Furthermore, mixed application architectures will emerge for meeting different real-time levels. The analysis of the example yielded a near real-time process. Due to restrictions in the process (e.g. manufacturing lead times, coordination efforts regarding consistent data), data timeliness and refreshing in seconds create no adequate benefit and business value, especially considering the associated increase in costs. Thus, investments in a real-time infrastructure are not meaningful in the considered use case. There is no trade-off with the application in case of falling investment costs. Related to the degree of organizational benefits (y-axis) and the effort caused by enhancements or new IT implementations (x-axis), the process portfolio matrix allows the qualitative assessment of the meaningfulness of real-time IT development projects. Often, a reasonable compromise between time and costs is required. A precise assignable purpose of quantitative Net Benefits is still pending and is being investigated by the authors in further research and additional case studies.

An adaptation of the indicators is recommended when a displacement of the process of the light grey areas towards the dark grey areas in the portfolio matrix is intended. This has two perspectives. To come from the process, the infrastructure has to be adjusted corresponding to the requirements. But then a business process redesign is also conceivable. According to Clark and Stoddard improvements in performance already result from process redesign without changing the infrastructure, but the incremental gains "are much less than the gains possible from combined innovations that merge technological and process innovations." (Clark and Stoddard 1996). By adjusting the indicators, a systematical process change in the direction of a real-time characteristic may also be achieved. Supporting such a redesign, the indicators can be used as a kind of checklist. Out of that it can be derived, which kind of changes will be needed to achieve real-time suitability. If a company aims to introduce an in-memory solution, the processes need to be accordingly adjusted. Otherwise there will be no significant impact on the process (process benefit gap). The process changes caused by the implementation of various measures
are associated with specific costs that have to be compared against the resulting economic benefits.

Using the proposed assessment model provides the opportunity to transform to stronger real-time driven supply chains (customers may still conduct modifications near delivery date, increased individualisation in the supply chain). Until now the value of real-time and in-memory technologies is merely suitable for a limited (but increasing) number of business processes. In future research we will try to locate processes that are appropriate for real-time system support. Furthermore, the next steps are the accurate determination of costs and benefits to allow a profitability analysis. For the validation of the model, further case studies are being examined. It has been shown that processes in the manufacturing industry are qualified. In addition, a further differentiation of the indicators is planned to meet the demand for completeness of the requirements for real-time assessments and the derivable cost-benefit ratio.

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