Information Systems for Retail Companies

Challenges in the Era of Digitization

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Abstract. Worldwide the retail sector is driven by a strong intra-competition of existing retailers and an inter-competition between traditional and new pure digital players. The challenges for retail companies can be differentiated into a business and an application system (architecture) perspective.

Based on a domain-oriented architecture that covers all steps of value creation through to the customer, the potential influence of digitization on the tasks of Retail Information Systems are examined from five different perspectives. The domain perspective is divided into five levels: master data, technical processes, value based processes, administrative processes and decision oriented tasks.

The technical challenges of application systems are not least characterized by the complexity of such architectures. The traditional mass data problem in retail is increasing in times of big data and several different omni-channel-scenarios. This leads towards really large enterprise systems, which require an understanding of the main challenges in the future. So, that the IT manager can gain and keep the flexibility and the software maintenance of applications (and the application architecture).

Keywords: Digitization · Retail · IS complexity · Application architecture

1 Corporations in a Globalized World

The effect of digitization is not independent of the institutional context, as, if nothing else, the investigation of North has suggested [1]. The institutional conditions are continuously shaped by decades of globalization of companies that has led to a considerable concentration on national and international markets. Trading companies have been intensively competing on particularly concentrated markets, mainly oligopolies, for a long time. Many trading businesses have reached a huge market size when revenue or number of employees serve as a rule. What is more, industrial companies have been carrying out trading functions all along, such as mineral oil traders Exxon or Shell in the Oil and Gas branch.

The existence of retail corporations (even though the term "trading company" would reflect the object of investigation more precisely since it refers to companies that

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are equally active in wholesaling or retailing, for the sake of common practice we will instead only use the term “retail company” to refer to such aforementioned companies that exercise wholesale or retail functions) has been a subject of academic discussions for decades [2]. Regardless of the institutional economic discussion about retail enterprises, the tasks intended by retail functions are beyond dispute and economically necessary too. They are expressed at the levels of goods, money/capital and information in four different bridging dimensions (see Fig. 1): bridging space by classic logistical functions, transportation and handling, bridging time by the classic function of warehousing, bridging quantities by the function of handling and bridging quality by manipulating or upgrading the goods.

Bridging Elements	Space (TU)	Time (L)	Volumes (U)	Quality (W)
Goods	Distribution of retail objects in real goods flows			
	Transport from A to B	Inventory function through keeping stocks	Merging, separating, commissioning	Sorting out, finishing, manipulating
Money	Distribution of payment objects to the flows of real goods			
	Transporting means of payment from A to B	Setting and monitoring payment deadlines	Collecting and dividing payment receipts	Determining the types of payment or payment securities
Information	Distribution of data objects to the retail and payment objects			
	Data transfer	Data storage	Collecting, processing, scanning	Consolidating, linking, interpreting data

Fig. 1. Digitization of retail corporations – analysis from a macro perspective

Against the backdrop of increasing concentration of companies within a branch and most notably the increasing extension of companies over multiple value-added steps and taking into account today’s degree of digitization in organizations, it seems sensible not to structure domains too narrowly, but rather to choose a higher degree of abstraction. Thereby, application architectures can also be described by overarching value chains.

This requirement by many verticalized concerns such as H&M, Tom Tailor, Nike, Adidas, Zara, Tesco, etc. has led to the development of a domain oriented architecture for information systems that encompasses all value-added steps from the production through to the customer [3].

The development of an architecture along value-added chains takes place according to a two-dimensional structural pattern. The first dimension in line with a shell model makes a distinction between the type of task, which fundamentally starts with the master data, without which no processes are possible, and proceeds to technically dominated tasks, which are very machine-oriented, and even includes three different business management tasks (direct value-added tasks in operational terms, administrative tasks and finally decision-oriented tasks) (see Fig. 2).

The individual, business management specifications of tasks, which also together represent the form of the dispositive factor, form the second dimension. They are characterized by the relevant value-added stage, so that, taken together, they produce individual application system architectures for industry, wholesalers, retailers and customers. They take into account the potential variety of functional requirements, so that all the functional requirements can be systemized and also consolidated.

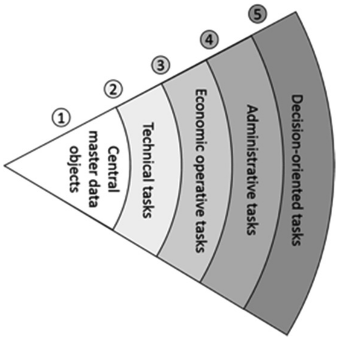

Fig. 2. The shell model underlying the domain oriented IS architectures [3]

Using the shell model, a structuring of all the functions for the retail and wholesale stage, which are necessary for completing retail tasks, has been completed for retail and wholesale corporations. This is very suitable for providing a standard framework for the different functions. The development of an architecture for information systems for tasks at a wholesale level (see the lower part for Fig. 3), is initially based on the master data, which affects the general conditions of operational business, particularly items, customers, companies and conditions (1st circle). The technical task areas are mapped based on the master data (2nd circle). The business management/operational processes (3rd level) at a retail corporation, which start with merchandise management from a tactical and operational perspective, are also based on the master data. Merchandise management covers purchase and sales considerations and forms the combination of these two tasks formerly separated in the “retail H model” [1]. The business management/administrative tasks are shown in the architecture for information systems for wholesale tasks on the fourth level and are to be viewed as a depiction of the value of the consumption of resources underlying the operational processes. The information for managing the company, which is required as part of controlling or for individual decisions about problems, is mapped in standard form in a layer known as “business intelligence” which makes available information for decision problems and ideally suggests a recommendation for a decision in algorithmic form (5th level).

The tasks for the retail stage can be structured in a similar way to the ideas for the wholesale stage (see Fig. 3 – upper part).

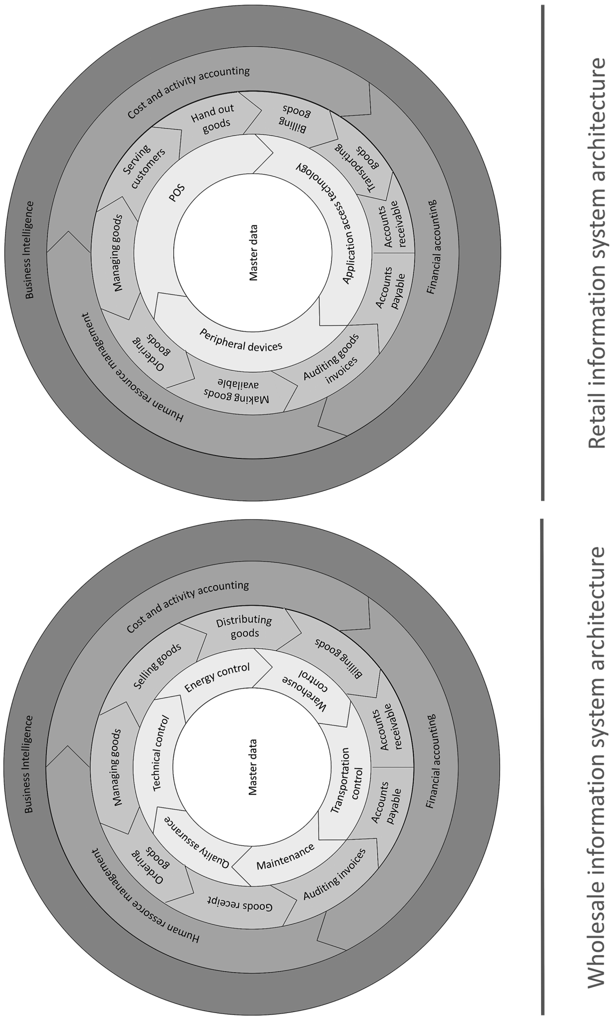

Fig. 3. Tasks in a wholesale and retail information system

2 Application Systems Challenges – Digitization Impact from a Domain Oriented Perspective

The current discussion about the “fashions” of digitization and “disruption” [4] caused by new technologies must be viewed critically from a scientific perspective. The impression is being given that there is a categorical difference between digital and “analog” corporations. Corporations or enterprises have been viewed as sociotechnical systems in business management theory for decades. This understanding of corporations still continues and there is no need to adapt this definition: No wholly digital company exists. At least the stockholders in each company are individuals or institutions. There are therefore still system elements of a technical and social nature in each corporation. It has now become normal to talk about "digital corporations" or "digital players", but it is important to state that this contradicts the facts.

The phenomenon of digitization however has to be rated as especially efficacious. By way of illustration [5], one might invoke a metaphor that is based upon the mathematical function of $2\ n - 1$. For now, let n be limited to the number of squares of a chessboard, that is 64. The function yields the number of rice grains for each square, given one doubles the number of grains from square to square: On square 1, there would be 1 grain, on square 2, there would be 2 grains, on, square 3, there would be 4 grains, and so on. Then, the number of grains would grow to approx. 8 billion grains in total through square 32 and approx. 18 quintillion in total through square 64. As Brynjolfsson and McAfee [6] elucidate this constitutes the difference between a large rice field - a still conceivable magnitude - and a volume of rice exceeding that of the Mount Everest - a much less imaginable dimension that results from said power function. The phenomenon of digitization however is not only characterized by a single power function that is derived from Moore's law for the rudimentarily yearly doubling of computational power per dollar, but also from the addition (maybe even multiplication) of multiple power functions, for in other disciplines such as material science (otherwise, 3D printing would not be that relevant), genome research, robotics and kinetics similar developments can be observed. Furthermore, the power function is not limited to 64 as is the case on the chessboard. As a result, the opportunities of invention are so comprehensive, that not only the Mount Everest should serve a metaphor, but the Himalaya itself which figuratively speaking can be produced over and over again in discretionary fields and whose volume is only limited by today's scientific boundaries.

It is important to recognize that all these opportunities for invention and thus later on for innovation lie beyond our ability of prognosis and moreover that these opportunities illustrate the importance of integrating matter and information which will become a part of application development in a domain context.

The following analysis focuses on the problem of identifying potential that already exists in different areas of retail information systems and is expected by the author. It is presupposed that there is a discrepancy between the current and the possible state of digitization in a retail information system, i.e. digitization potential of more than zero exists (problem presupposition). We also assume that there are and will be technologies, which determine the degree of digitization potential (technology potential presupposition). The technologies underlying the following remarks, which have been used in our forecast of possible digitization potential for information systems, need to be outlined before discussing the digitization fields. No importance is placed on any possible classification or typification of technologies. Instead, a McKinsey study will be used as an example, which makes an important distinction in the sense of the technology potential presupposition. It was prepared between the technology's depth of impact and the medium- and long-term probability that it will occur and also for the consumer goods industry and the retail sector [7]. Figure 4 primarily focuses on 3D printing, the Internet of Things, advanced robotics, big data (and therefore also on advanced marketing shown separately in the figure), the mobile world and artificial intelligence as the enablers of new opportunities.

These developments are identified as primary trends. Trends like cloud computing, sensors and actuators, natural interfaces and the huge expansion of networks, storage capacity and processor capabilities have also become established as secondary trends.

In principle, all the trends create a situation where data formerly not accessible to information systems is subjected to processing so that the data volume to be handled and the execution capabilities of the application systems and the hardware have to increase. It has only become clear recently which development paths have to operate relatively quickly, even if the familiar concepts for designing the systems do not represent any new findings scientifically. However, because of the new opportunities and the level of digitization achieved, the solutions can be implemented. This difference is possibly most clearly evident with artificial intelligence. It is a subdiscipline of computer science, which has a long tradition and has already developed many methods and solution principles in the past and could achieve a breakthrough in many application fields in the near future.

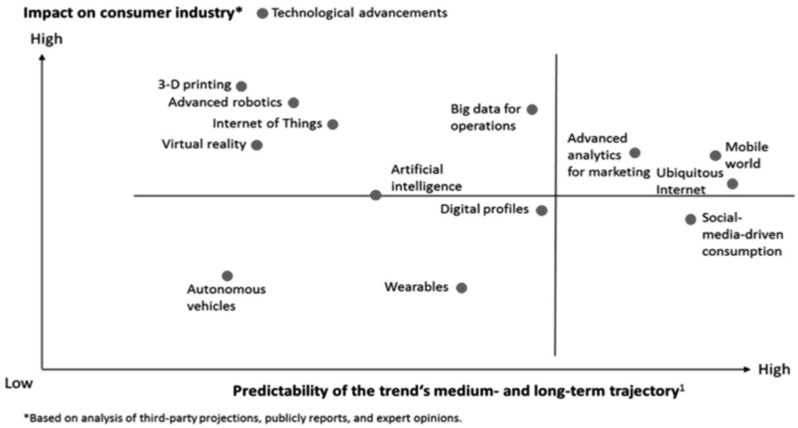

Fig. 4. Assessment of the effectiveness of technologies for customers [7]

There is a basic trend that information and objects grow together. This also triggers a need to consider all-round approaches when shaping application systems, as they find expression particularly in the integration of systems in business information technology.

2.1 Considerations on the Master Data Level with Increasing Digitization

A value-added oriented analysis of typical digitization potential is designed to initially focus on the core of all the application systems, following the shell model: i.e. the master data. Through the Internet of Things, it is possible for information and objects to become one, as it were. It is even possible to document the data on the surrounding conditions of the object and the interaction conditions of customers, which are constantly changing. This new reality will fundamentally change the master data situation in application systems. Structured and non-structured object information will grow closer. This will become more and more relevant for customers and their information requirements and there is a need to break through any thresholds between the application systems in industry and retail, which still exist, since faulty information about products, even in the form of photos of products and brands, is far too often the cause of enormous inefficiencies and sub-standard customer information in the processes nowadays. In addition to extending the master data perspective to the complete value-added chain and the increase in quality demands on the master data, the scope of master data is increasing too. Alongside ever more comprehensive information, which the law requires, there are also elements like location information, transport path information, CO2 footprints etc., which open up new information possibilities covering complete performance objects in the economy by bringing together the object and information; this is not only relevant for the corporation's system, but also for the diverse peripheral systems at an enterprise.

As a result, master data can firstly expect to grow in importance in terms of the integration perspective of the value-added chain and, secondly, as regards the scope of the information. Thirdly – and this seems to achieve a particularly long-term change in master data management in the view of the author – the question arises as to whether master data in the past was adequately mapped in terms of the character of the real objects represented in systems. Master data is that data on a real or conceivable object, which only exists in a time and space continuum. The modelling of time in conjunction with the master data, however, only has a short-lived tradition, for usually price information (purchase and sales prices) is handled in the systems related to time – but not the information on the object itself. This affects the grouping and classification logics used in systems. For example, one set of material master data in industry is embedded in standard hierarchies, but in retail information systems, groups of goods are the typical way of categorizing items and this is normally geared towards product features (e.g. food groups like yoghurt, butter, chocolate). In addition, the items are assigned to an external product classification, like the global product classification code at GS1, which also helps to conduct a comparison of sales between retail corporations.

This grouping of items creates a situation in enterprise system architectures with data warehouse systems, where, if changes are made in the assignment of groups, reclassification has to take place, which is problematic for operating the system, as millions of data sets have to be set up once again. This is based on methodically faulty modelling or non-modelling of time in master data, which was, however, necessary in the past. The individual objects are taken in their own right and depend on time in their assignment to a group. This applies all the more if the promises provided by the Internet of Things are met. The features of an object should always be available in a time-dependent manner in an information technology world without any technical restrictions in the system. The systems would create a completely different picture of master data if the demands of sensors and actuators were seriously considered, as the characteristic difference between master and transaction data – at least on the level of objects – would disappear. This fundamental modification of master data in the systems would also enable a different perspective on customers. It is also true that customers should not be mapped in a time-dependent manner, but many of their attributes can only be interpreted like this.

2.2 Digitization Potential at a Technical Task Level

The technical tasks are arranged on the second level of the IS architectures and they help integrate very machine-oriented information in applications for management and control purposes or directly in machines as embedded systems. These applications establish integration in the context of the Internet of Things, ubiquitous computing, the mobile world, etc., which was not normal in this form in the past. This newly available information allows the establishment of new kinds of processes. For example, sensible maintenance intervals or maintenance requirements can be determined at retail corporations for a large number of technical devices, ranging from freezers, fresh food areas, tills at stores to warehouse equipment and conveyor vehicles and trucks in the future (predictive maintenance), instead of planning this in advance. This enables corporations to make huge savings in maintenance, for the current practice of agreeing maintenance intervals between the investment goods manufacturers and the retail corporations in advance is very often uneconomical for retail enterprises.

In addition to the example of optimizing maintenance costs, energy controls are a second important area where considerable improvement opportunities open up through digitization and the controls available for electronic devices. This initially concerns the basic capability of controlling devices based on sensor information about temperatures, air conditions, etc. and opens up a whole new set of different control options for refrigeration units and other power-consuming devices. When retail corporations draw up contracts with energy suppliers, decisions also have to be made about the times of the day when maximum energy is consumed (or until when). These peak loads, in turn, are responsible for the costs of the contracts.

In conclusion, it is possible to state that the process innovations outlined here offer enormous potential in important resource areas at retail corporations – not only those in warehouses, but also those at retail enterprises.

2.3 Digitization Potential at an Operational Task Level

The operational tasks, by definition, involve those that are vital for the retail corporation's value added. The key task of a retail enterprise consists in ensuring that sufficient quantities of products are available in a combination of product lines at competitive prices. The key areas of competence required for a retail company involve the production or purchase of items at prices that are as low as possible (production, purchase, procurement and sales function), "designing" good items, a cheap purchase price, establishing product lines and placing them on the shelves or on websites and setting competitive or profitable sales prices. The special offer or campaign business with its independent definition of product lines, prices and positioning and the special challenges of logistics should also be mentioned.

During the last few decades, little has changed in the functions mentioned here, which are devoted to the central object of goods at retail enterprises. The fierce quality and price competition in Germany has created a situation where a personnel-oriented resource policy has largely been pursued – i.e. the oligopolists have attempted to cope with the tasks through the employees' qualifications or hiring them from rivals. Application systems have only played a secondary role, for the definition of requirements has been primarily geared to customer needs and this has only permitted automation in certain areas. This automation opportunity for operational tasks (managing prices, creating and managing listings etc.) will be increasingly linked to decision automation in the future, which is arranged on the fifth circular level of the IS architectures. The more technologies that are introduced like the approach followed by SAP for an in-memory database with the many associated optimization measures, the less potential there will be for the operational level to independently exist without the decision level. The operational tasks and the decision tasks can therefore be viewed together: Firstly, they enable an enormous leap in effectiveness, which would primarily be assigned to the decision level (automation of decision-making or thinking, so to speak). Secondly, a leap in efficiency for the operational tasks would be possible, strictly speaking, and this is primarily achieved by automating actions.

In addition to the marketing mix parameters, special focus is required for optimizing logistics processes in line with supply chain controls. The logistics costs from the supplier to the shelf at a retailer or to the customer represent the most important type of expense alongside other human resources costs and the rent. As part of increasing multi-channel offers, the significance of this cost component will continue to grow, for the delivery of the goods to customers is added as a further cost dimension (and the rent becomes less important in contrast to an in-store retail company). The logistics tasks at retail enterprises are logically differentiated between the two main processes of procurement and distribution logistics, which can also be intertwined with each other in time synchronization.

2.4 Digitization Potential at an Administrative Task Level

No radical process changes are expected for administrative tasks, which initially do not provide any value added as cross-sectional tasks. However, administrative tasks are expected to accelerate as information is available more promptly and processes are geared towards real time. The current practice of presenting accounts for certain periods does not match the need for prompt reporting about the company's economic and financial situation for managers.

The ongoing process of digitization involving efforts lasting decades to improve electronic data exchange, the increasing refinement of information from the receipt to the item level, the opportunities of exchanging data with industry and the pressure to be able to make available the latest, high-quality master data for consumer purposes will trigger enormous efficiency potential and a significantly more informative analysis basis in the areas downstream, automation in bookkeeping and make the preparation of assessments more flexible.

2.5 Digitization Potential for the Decision-Oriented Task Level

There have been some experiments with artificial intelligence tools, for example, to optimize pricing policy, but there are no all-round strategic competition models or sophisticated game theory points of contact. The aspect of forming product lines has been neglected by retail corporations in their systems too.

In the future, new digitization opportunities will particularly open up enormous potential for improvements in the value-added areas. Initially, real-time-oriented simulations will be able to reduce the acceptance barrier for using systems in the most important area at retail enterprises. Simultaneous optimization – for a retail corporation's set goal – of the different parameters in the marketing mix at retail companies will be part of the future, because the data now available enables intelligent and retail-experienced users to formulate hypotheses and falsify them by using real data in order to gain increasingly refined findings about customers and competition events through permanent checks. Based on the data available, oligopolistic assumptions about behavior (in the form of price leadership and its associated behavior) can already be confirmed. The normal trend at retail enterprises at the moment of believing that prices and product lines in the existing dimension can be controlled by people contradicts the actual situation at retail corporations. The responsibility for many thousands of items in a product line section is not economically feasible for individual managers; even the scope of responsibility at discount stores contradicts the findings about human processing capabilities. Arguments are usually presented with reference to the company's behavior in the past or references to the competition, although both argument chains do not necessarily lead to an ideal offer price. Current practice at retail corporations is not rationally justifiable and the following will be crucial in the future: There are much more effective and more efficient opportunities by involving intelligent algorithms and the application systems supporting them. Whether a simulation of the purchase prices based on the ingredients, which is linked to the development in the prices of raw materials, is used to calculate purchase and sales prices for different quantities at different sales channels or a quantity-weighted sales price analysis of rivals is used to offer industry's own sales price needs – there are many examples available. According to the author, the product line policy as the most relevant economic task is not adequately supported and there are too few experts particularly for this task.

3 Application Systems Challenges – Technological Perspective

The outlined potentials of and requirements on the tasks of trading companies will have to be modelled on the application system level, leading to even further complex application architecture, even though and because digitization progresses and actions to external demands have to be taken. The application architectures of companies are shaped by the data-driven system size, the plurality and pluralism of the systems in use and the degree of change of the single system [8] or taken together by the complexity of the system landscape (complexity as a measure for variety and dynamics of a system) [9]. Information systems in trading and retailing have to administrate and process enormous amounts of data by now and the growth is formidable. The total volume of data at Walmart, the largest trading company world-wide, amounts to about 30.000 TB [10]. Per year, 13 billion consumer baskets have to be processed [11]. Still many companies only store information on receipt level instead of item level and even more only allow access for a certain time span, e.g. two or three months.

A further restriction that has been assumed, is the dominance of standard systems in the context of Enterprise Systems and the thereby predefined number of different systems [12]. Enterprise Systems are widely understood as an advancement of ERP-II systems and consist of an ERP core, a CRM, an SCM and a BI system (with many further individual products/systems that are operated by the companies [13]. One can observe a high number at that, as an example may illustrate:

Assume the following systems in a retailing company: ERP, PIM, SRM, Financial, HR, CRM, SCM, SRM, Forecast & Replenishment, Category Management, Online Shop, Online Marketing, Middleware, POS Data Management, POS System and Peripheral Control. Then, already 16 system types have to be managed. These products are usually developed in releases, considering that the individualization of standard solutions requires professional release management. This release management however has to account for the software logistics that provides a concept for multi-stage development systems, quality assurance systems, production systems, sandbox systems, training systems, consolidation and performance test systems. As each of the above-mentioned 16 system types is instantiated for each purpose - let's just say for the 4 purposes of development, QA, production, training – one obtains the number of systems that have to be operated by multiplication, that is 64 systems in the sample concern. What is more, when as part of a template approach the systems are operated in multiple computing centers, the number of system embodiments multiplies once again. Assuming a factor of 6, the number of systems amounts to 384.

If alternative releases are in use, another multiplication supervenes. Even though, this does not necessarily mean a reduplication, possibly more than 700 systems have to be operated.

In reality, there is a plethora of additional systems, that have to be operated for reasons not to be presented here. Thus, from an Enterprise Systems perspective, more than 1000 systems may have to be considered. This complexity presents challenges to project management, requirements management, integration management, test management, development management and software logistics in an extent that greatly surpasses the problems discussed in literature. By reference to a requirement from an omni-channel scenario this complexity is illustrated in the following. When it comes to an omni-channel offer of a wholesaler or retailer, the question arises how the price calculation is to be formulated if customer price differentiation and same prices at all channels is required at the same time. Such a scenario at a traditional brick and mortars retailer with a cash system who wants to offer and sell products online will result in situation, where the price calculation logic that is implemented on the one hand in the cash system but on the other hand has to be changed in the back-end system for the online shop, so that both channels access the same functional building blocks. But then, the offline/online difficulty has to be modelled, since in today's trading companies there are no pure synchronous online connections, but always hybrid scenarios of online functionalities that involve functions that are only available offline for reasons of technical restriction.

The degree of change of the systems however is determined by especially two causes: first, by the strategy and system manifestation of the standard software producer and secondly by the strategy and system requirements of the domain company, i.e. the company that uses the software.

At first glance, one has to state that the Enterprise Systems market is dominated by few vendors: it can be characterized as a supply oligopoly. This background competition policy must always be considered at the domain companies, as there are distinct principal-agency problems that are debated insufficiently even though they can lead to significant problems because of diverse information asymmetries. But the strategy of the software producer presents a paradigmatic restriction for the domain company so that an adoption of the software producer's strategy is required for the trading company. For instance, SAP has provoked a pressure for change at the customers' sides when – with the development of the SAP HANA database and the (partially) newly designed applications such as S/4 HANA Financials, Merchandise Management etc. – they announced the end of the maintenance period for 2025. Hereof, the degree of change is at times very high, since SAP has completely change a number of functions due to new architecture principles. For example, following the strategy of abandoning aggregated data (by integrating OLAP and OLTP), new processes are created and the implementation of the system does not only change single applications, but the entire system architecture. This means, that a strategy for the comprehensive application architecture is require in order to prevent product specific responsibilities and perspective which in turn lead to a subpar solution. A further dimension of complexity is elicited by the fact that applications are being narrowed for service considerations and cloud use cases. In order to be economically advantageous in the cloud, standardization is needed which is currently not the case. Therefore, the implication is not to realize existing demands with cloud solutions. In many case, the only alternatives are "Standardization 2.0" in the cloud vs. on premise usage. If a cloud service is used, the problem of system integration emerges. There are many cases in the past, where an order in a Salesforce system could not be integrated in an SAP system. Hybrid approaches that allow for a connection of Software as a Service and self-operated application will become an integral part of the architecture and application management.

The domain company itself has also its own release strategy, that covers the integration of changes by the standard software producer – via releases and patches – and the realization of requests by the domain company itself. Ultimately, the functional and technological changes coalesce in the release management, independent from the origin of the change.

The change of complex application systems and architecture requires – as elaborated on – among others multi project management, cross-application requirements management, integration management, integrative test management. The integration of separated tasks becomes necessary and an essential success factor for the management of system landscapes in a world of applications that is subject to change.

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