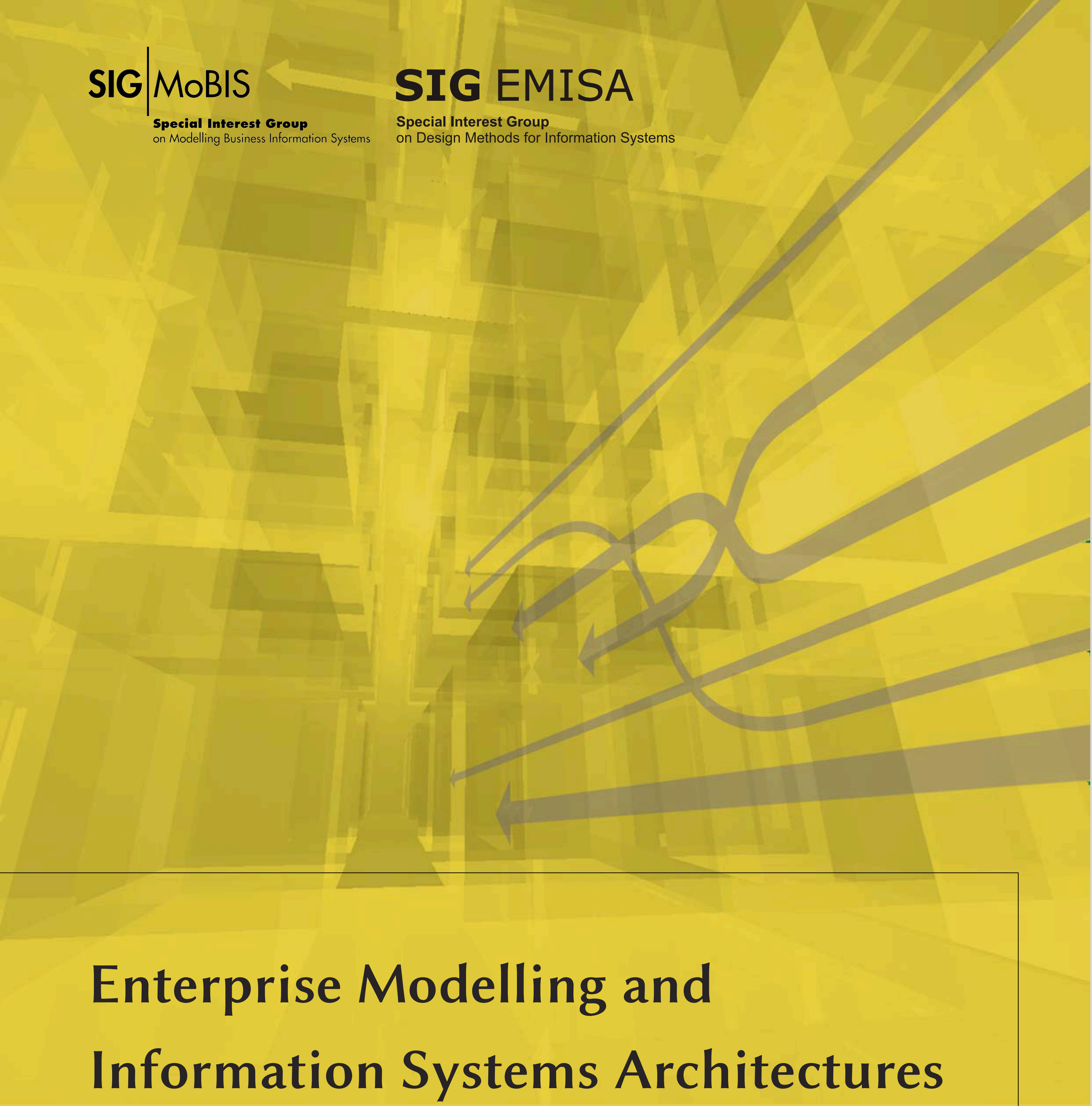

SIG MoBIS
Special Interest Group
on Modelling Business Information Systems

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on Design Methods for Information Systems

# Enterprise Modelling and Information Systems Architectures

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# Editorial Preface

In 2011 the IEEE Technical Committee on Electronic Commerce decided to broaden its scope and, accordingly, rename itself to the IEEE Technical Committee on Business Informatics and Systems. In line with this change in name and scope it decided to rename its flag ship conference to IEEE Conference on Business Informatics (CBI). Following these changes, it has been a first priority of the technical committee to exactly define the meaning of the term "Business Informatics" in an IEEE context and to underpin the need for a Business Informatics Conference under the umbrella of the IEEE.

Evidently, the IEEE as the Institute of Electrical and Electronics Engineers, the world's largest professional association for the advancement of technology, takes a mainly engineering sciences direction when approaching Business Informatics. In order to find its own scope for the IEEE Conference on Business Informatics, we have been inspired by Nygaard who defined informatics as the science that has as its domain information processes and related phenomena in artefacts, society and nature. In the spirit of this definition, we consider Business Informatics as a scientific discipline targeting information processes and related phenomena in a socio-economical context, including companies, organizations, administrations and society in general.

A key characteristic of Business Informatics research is that it considers a real-world business context in developing new theories and concepts that enable new practical applications. Thereby, Business Informatics research does not only extend the body of knowledge of the information society, but at the same time provides a tangible impact to industry. Consequently, Business Informatics is a fertile ground for research with the potential for immense and tangible impact. Or put it in other words - Business Informatics is research that matters!

There is no doubt that Business Informatics is an inter-disciplinary field of study. It endeavours taking a systematic and analytic approach in aligning core concepts from management science, organisational science, economics information science, and informatics into an integrated engineering science. Consequently, the field of Business Informatics involves a broad spectrum of more specific research domains that focus on important aspects of Business Informatics in the above mentioned context. For the first edition under the new title and scope, it has been important to sharpen the future research directions in the domain of Business Informatics. Thus, we had carefully selected appropriate research domains that represent the IEEE understanding of Business Informatics. In order to reach a common understanding of these domains in our community, we invited distinguished experts to introduce a research domain by defining its scope, its existing body of knowledge, and most importantly its future research challenges. These keynotes have been a means to guide the community in its way forward and provide directions for Business Informatics in the IEEE CBI context.

In this special issue of the EMISA journal we include seven papers, each based on a IEEE CBI 2013 keynote introducing a research domain in Business Informatics. Evidently, these papers are neither classical research papers nor pure surveys, since they focus to a large extent on the "future", i.e. the open research challenges (without providing a solution). In the following, we define the scope of the seven research domains and in parentheses we name the author(s) who introduce(s) the domain by a paper presented in this special issue.

1. Enterprise Architecture (Henderik A. Proper and Marc M. Lankhorst)
*Scope*: In contrast to partial architectures such as IT architecture or software architecture, enterprise architecture focuses on the overall enterprise. Enterprise architecture explicitly incorpor-

ates business-related concepts and artefacts in addition to traditional IS/IT artefacts. By embracing an enterprise-wide perspective enterprise architecture provides a means for organizations to coordinate their adaptations to increasingly fast changing market conditions which impact the entire enterprise, from business processes to IT support.

2. Enterprise Modelling (Ulrich Frank)
*Scope*: Enterprise modelling is concerned with the modelling of different aspects of an enterprise (goals, capabilities, organizational structures, business processes, resources, information, people, constraints, etc.) and their interrelationships. Accordingly, enterprise modelling offers different perspectives of an enterprise suitable for strategic planning, organizational design and software engineering. It covers the notation and semantics of enterprise modelling languages, the processes involved in creating and managing models, tool support, as well as quality of modelling.

3. Enterprise Engineering (Jose Tribolet, Pedro Sousa, and Artur Caetano)
*Scope*: The enterprise engineering domain aims to apply an engineering based approach to the design of enterprises and their transformation. As such, this domain is concerned with the development of new, appropriate theories, models, methods and other artefacts for the analysis, design, implementation, and governance of enterprises by combining (relevant parts of) management and organization science, information systems science, and computer science.

4. Business Process Engineering (Jorge Sanz)
*Scope*: Business Informatics deals with information processes in organizations, industries and society at large. This concept of "information in motion" links to business processes deeply. Processes are the expression of the behaviour of organizations and this behaviour leaves footprints in the form of artefacts of all sorts, including information. Thus, Business Informatics profoundly intersects with the social enterprise from a unique perspective, namely, the integration of information and people's behaviour.

5. Business (Model) & Service Innovation (Eng Chew)
*Scope*: Being successful in business no longer depends on having the "best" product, but increasingly depends on delivering high quality services, through attractive customer-centric business models, at affordable costs. This forces enterprises to continuously develop/ innovate their services and renew/innovate their business models. The world's evolution toward services-based clusters also brings new trends that blur the traditional boundaries across conventional industries, thus generating new opportunities for economies of scale and scope. This has led to increasing interests by disparate industries around the globe in the "art and science" of the practices of service innovation. A new concept, called service-dominant logic, has recently been introduced in the business discipline to study service phenomena - one that has significant cross-disciplinary implications for the research and design of IT-enabled service innovations and the attendant service systems.

6. Empowering & Enabling Technologies (Stephane Marchand-Maillet and Birgit Hofreiter)
*Scope*: Enabling technologies in Business Informatics integrate management practices with Informatics and Information Technologies. Business Informatics tasks may be performed, supported or monitored by automated or semi-automated technologies. Running environments range from thin mobile clients to large-scale distributed platforms, and newer areas such as analytics services, big data. Accordingly, we seek papers for original and innovative empowering and enabling technologies in domains related to Business Informatics.

7. Data-Driven Service and Market Engineering (Thomas Setzer)
*Scope*: Economic problems faced by today's organizations as well as society as a whole demand interdisciplinary knowledge from econom-

ics, management and informatics. Thus, economic modelling of IT-based solutions for analytically and statistically formulated economic problems is subject to this track. In particular, we are interested in the intelligent reduction of problem-relevant features from vast datasets Including customer dynamics, market behaviour, resource usage, etc.

It should be noted that these research domains represent cornerstones of the CBI conference series. However, it is our vision to complement the CBI picture on business informatics by other appropriate research domains. We plan to introduce these domains both at future CBI Keynotes and subsequent special journal issues.

All articles in this EMISA special issue were handed in by domain experts that have given a keynote presentation at the IEEE Int'l Conference on Business Informatics (CBI 2013), Vienna, 15th - 18th July 2013. These invited papers have then undergone a blind review for EMISA journal publication. Each paper had been assigned to two international reviewers. The reviewers for each papers have been chosen on the following criteria: The first reviewer has been a member of the IEEE CBI steering committee in order to ensure compliance of the paper with the scope of business informatics in an IEEE context. The second reviewer has been an accredited expert in the respective research domain not being involved in the IEEE CBI organization in order to ensure an open and unbiased representation of the domain. In the case where one guest editor is a co-author of the paper, the review process was managed by the other guest editor.

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Henderik A. Proper and Marc M. Lankhorst

# Enterprise Architecture

## Towards essential sensemaking

*In this position paper, we discuss our view on the past and future of the domain of enterprise architecture. We will do so, by characterising the past, and anticipated future, in terms of a number of trends. Based on these trends, we then discuss our current understanding of the future concept and role of enterprise architecture. We conclude by suggesting vantage points for future research in the field of enterprise architecture.*

## 1 Introduction

Increasingly, organisations recognise enterprise architecture as an important instrument to steer (or influence) the direction of transformations (Buckl et al. 2011; Greefhorst and Proper 2011; Lahrmann et al. 2010; Lankhorst 2012b; Op 't Land et al. 2008; The Open Group 2009). Over the past decades, the domain of enterprise architecture has seen a tremendous growth, both in terms of its use and development in practice and as a subject of scientific research. The roots of the domain can actually be traced back as far as the mid 1980s.

In this position paper, which builds on Proper (2012), we will review the evolution of the field of enterprise architecture. We do so by characterising both its history (Sect. 2), as well as its anticipated future (Sect. 3), in terms of a number of trends. Based on these trends, we also discuss our current understanding of the concept and role of enterprise architecture (Sect. 4). We conclude with a brief discussion of our view on research in the field of enterprise architecture in terms of key vantage points for further research.

## 2 A History of Enterprise Architecture

In this section we discuss the history of the field of enterprise architecture in terms of a number of trends as observed by us.

### 2.1 From Computer Architecture to IS Architecture

The origins of *enterprise architecture* can be traced back to the concept of *information systems architecture* (IS Architecture), which in turn has its roots in the concept of *computer architecture*. One of the first references to the term *architecture*, in the context of IT, can be found in a paper from 1964 on the architecture of the IBM System/360 Amdahl et al. 1964. There it was used to introduce the notion of *computer architecture*.

Later, in the 1980s, the term architecture started to become used in the domain of information systems development as well. This occurred both in Europe and North America. The North American use of the concept of architecture in an information systems context can (at least) be traced back to a report on a large multi client study, the PRISM[1] project Hammer & Company (1986) conducted, as well as the later paper by Zachman (1987). The European origins can be traced back to the early work of August-Wilhelm Scheer on the ARIS framework, also dating back to 1986 (Scheer 1986, 1988, 2000).

In Europe, the ARIS framework as developed by August-Wilhelm Scheer eventually formed the base of the well known IDS-Scheer toolset. In

[1]Not to be confused with the present day concept of PRISM http://en.wikipedia.org/wiki/PRISM_(surveillance_program)

North America, the PRISM project was a multiyear research project, led by Michael Hammer, Thomas Davenport, and James Champy. PRISM, short for Partnership for Research in Information Systems Management, was sponsored by approximately sixty of the largest global companies (DEC, IBM, Xerox, Texaco, Swissair, Johnson and Johnson, Pacific Bell, AT&T, etc.). This research effort produced an architecture framework known as the PRISM Architecture Model, which was published in 1986. The PRISM framework has strongly influenced other enterprise architecture standards, methods and frameworks (Beijer and De Klerk 2010; Davenport et al. 1989; Richardson et al. 1990; Rivera 2007).

Many years later, the PRISM report also influenced the IEEE definition of architecture, as many of the IEEE 1471 committee members were employed by the original sponsors of their earlier work on PRISM. Key people involved in PRISM later also spearheaded the wave on Business Process Reengineering (Davenport et al. 1989; Hammer 1990), which is essentially an early business architecting effort.

The Zachman (1987) paper is often referred to as one of the founding papers of the field of enterprise architecture. It should be noted, however, that both the PRISM and ARIS frameworks predate the Zachman framework, although these frameworks have indeed been published in less accessible sources.

The important message of the ARIS, PRISM and Zachman frameworks is the need to consider *information systems* from multiple perspectives based on stakes, concerns, as well as different aspects of the information systems and its business or technology context, while at the same time focusing on the key properties of the information system. The latter focus is also captured by the phrase *fundamental organization* in the IEEE 1471 IEEE 2000 architecture definition: "*the fundamental organization of a system embodied in its components, their relationships to each other and to the environment, and the principles guiding its design and evolution.*", where *fundamental* is dependent on the key concerns/stakes of the stakeholders involved in an architecting effort.

The basic idea to consider information systems in a holistic way, i.e., from multiple related perspectives, was actually already identified before being linked to the term *information systems architecture*. For example, Multiview Wood–Harper et al. (1985) already identified five essential viewpoints for the development of information systems: Human Activity System, Information Modelling, Socio-Technical System, Human-Computer Interface and the Technical System. Even though the authors of Multiview did not use the term *architecture*, one can argue that Multiview is effectively one of the earliest explicit information systems architecture frameworks. During the same period in which Multiview was developed, the so-called CRIS Task Group of the IFIP working group 8.1 developed similar notions (Olle et al. 1982, 1983), where stakeholder *views* were captured from different perspectives. Special attention was paid to disagreement about which aspect (or *perspective*) was to dominate the system design (viz. "process", "data" or "behaviour"). In the early 1980s, the CRIS Task Group already identified several *human roles* (stakeholders!) involved in information system development, such as *responsible executive*, *development coordinator*, *business analyst*, *business designer*, quite similar to the stakeholder dimension of, e.g., the Zachman framework.

In the 1990s, challenges such as interoperability and distributed computing resulted in the creation of reference architectures, including the CIMOSA (*Open System Architecture for CIM*) framework for computer integrated manufacturing systems ESPRIT Consortium AMICE 1993 and the RM-ODP (*Reference Model for Open Distributed Processing*) framework for information systems (ISO 1996a,b, 1998a,b)

## 2.2 From IS Architecture to Enterprise Architecture

The awareness that the design of information systems needed to be seen in a broader business and enterprise context, triggered several authors to shift towards the use of the term *enterprise architecture* rather than *information systems architecture*. One of the first authors to use the term *enterprise architecture* was Spewak (1993).

The initial architecture approaches focused on the development of information systems, while taking the models/architectures of other relevant aspects of the enterprise as a given. However, due to the strong connection between business processes and the underlying information systems, it was only natural to not just treat such perspectives as a *given*, but rather to *co-design* these in tandem with the information systems and their underlying IT support.

Earlier versions of TOGAF (The Open Group 2005), including TAFIM (1996), treated *business architecture* as a *given* thing. By defining *Enterprise Architecture Planning (EAP)* as "*the process of defining architectures for the use of information in support of the business and the plan for implementing those architectures*", Spewak Spewak 1993 also seems to suggest to take *business architecture* as a *given*. Boar (1999) in "*Constructing Blueprints for Enterprise IT architectures*" does the same.

The shift from taking a *business architecture* as a given input, to the realisation that business and IT should be co-designed as a whole, could be seen as the birth of modern day *enterprise architecture*. The *strategic alignment model* by Henderson and Venkatraman (1993) has played an important role in taking this step to the co-design of *business architecture* and *information systems architecture*. Henderson and Venkatraman (1993) indeed suggests that aligning business and IT should not necessarily require that the business strategy should be treated as a given. There are several ways to align business and IT. Also the work by, e.g., Tapscott and Caston (1993) contributed to this realisation, as well as the work by Ross et al. (2006). The earlier mentioned work on Business Process Reengineering (Davenport et al. 1989; Hammer 1990), essentially an early business architecting effort, also contributed to this shift.

Without an attempt to be complete, some enterprise architecture approaches that indeed take a more co-design oriented perspective include: the Integrated Architecture Framework (IAF) (Goedvolk et al. 1999; Wout et al. 2010), the ArchiMate (Jonkers et al. 2003; Lankhorst 2012b) language, as well as the DYA (Wagter et al. 2001, 2005) and DEMO (Dietz 2006) methods. Also the most recent version of TOGAF (The Open Group 2009) does indeed suggest to co-design the business architecture and the information systems architecture.

### 2.3 From Business-to-IT-stack to Enterprise Coherence

The realisation that information systems architecture and business architecture need to be co-designed in tandem, led most enterprise architecture approaches to capture a business architecture in terms of building blocks such as business services, business processes, business actors, etc. These business building blocks were then linked to information systems, and ultimately IT infrastructures, resulting in a '*Business-to-IT-stack*'. Among an increasing group of researchers and practitioners, the 'reduction' of 'the architecture of the enterprise' to a '*Business-to-IT-stack*' caused unease. In particular Graves (2008), Fehskens (2008) as well as Wagter (2009) have argued that such a Business-to-IT-stack centricity is a major weakness of contemporary enterprise architecture approaches, and that enterprise architecture should involve many more aspects of an organisation, such as a clear connection to its strategy, its financial structures, the abilities of its work force, etc. More specifically, Wagter (2009) argue that enterprise architecture should not just be concerned with Business-IT alignment, but rather with the alignment of all relevant aspects of an enterprise. Therefore, rather than using the term *alignment*, Wagter (2009) suggest to use the term *enterprise coherence* to stress the multifaceted nature.

A first enterprise architecture method to indeed explicitly move beyond a Business-to-IT-stack centricity is the GEA method (Wagter 2009). GEA argues that the coherence between several aspects of an enterprise needs to be governed explicitly by means of an enterprise architecture. To indeed co-design the different aspects of an enterprise architecture, and to use it (both the co-design process, and the resulting architecture) in governing enterprise coherence, it is necessary to take the concerns and associated strategic dialogues of senior management as a starting point. In other words, the way in which architecture is integrated into the strategic dialogue should take the concerns, language, and style of communication of senior management as a starting point, and not the typical domains, layers, or columns, as identified in the traditional architecture frameworks.

The shift from Business-to-IT-stack centricity to the broader notion of enterprise coherence also required a change in perspective on change processes in organisations (Wagter et al. 2011). De Caluwé and Vermaak (2003) have identified a number of core perspectives on change processes in organisations:
1: *Yellow-print thinking*: Bring the interests of the most important players together by means of a process of negotiation enabling consensus or a win-win solution.
2: *Blue-print thinking*: Formulate clear goals and results, then design rationally a systematic approach and then implement the approach according to plan.
3: *Red-print thinking*: Motivate and stimulate people to perform best they can, contracting and rewarding desired behaviour with the help of HRM-systems.
4: *Green-print thinking*: Create settings for learning by using interventions, allowing people to become more aware and more competent on their job.
5: *White-print thinking*: Understand what underlying patterns drive and block an organisation's evolution, focusing interventions to create space for people's energy.

As argued in Wagter et al. (2011), most traditional approaches and frameworks, including the Sowa and Zachman (1992) and IAF (Wout et al. 2010) frameworks, the ArchiMate (Iacob et al. 2012; Lankhorst 2012b) language, as well as the DYA (Wagter et al. 2005) and TOGAF (The Open Group 2009) architecture methods, essentially take a Blue-print perspective on change. The need to really involve senior management, however, suggests the use of another style of thinking, involving internal or external stakeholder interests, strategy formulation processes, formal and informal power structures, and the associated processes of creating win-win situations and forming coalitions. In terms of De Caluwé and Vermaak (2003) this would suggest to complement the Blue-print perspective with the Yellow-print perspective, and arguably also a mix of the other perspectives.

In the development of the GEA method (Wagter 2009), this line of thinking was taken as a starting point. As a result, the actual political power structures, and associated strategic dialogues, within a specific enterprise were taken as a starting point, rather than the frameworks suggested by existing architecture approaches. This leads to enterprise specific frameworks of *coherence governance perspectives*, to manage enterprise coherence. For example, in terms of 'mergers & acquisitions', 'human resourcing', 'clients', 'regulators', 'culture', 'intellectual property', 'suppliers', etc. The existing Blue-print oriented frameworks can still be used to further structure the dialogue between the coherence governance perspectives, especially where it concerns issues pertaining to the Business-to-IT-stack.

It is to be expected that organisations aiming to use enterprise architecture to steer major transformations, will increasingly move from a Business-to-IT-stack centricity perspective to an enterprise coherence perspective on their enterprise architectures.

### 2.4 From Big-Design-Up-Front to Fit-for-Purpose

Early frameworks and languages for enterprise architecture (Lankhorst 2012b; The Open Group 2005; Wout et al. 2010; Zachman 1987) were primarily concerned with the identification of the aspects, concepts and domains that should be included in an architecture; hence the resulting *content frameworks*. This orientation brings along the risk that architects focus more on completeness of architecture descriptions, rather than on ensuring that the descriptions meet the purposes for which they are actually needed. Accepted standards for defining architecture, such as the earlier quoted IEEE 1471 IEEE 2000: "*the fundamental organization of a system embodied in its components, their relationships to each other and to the environment, and the principles guiding its design and evolution.*" do not provide a clear 'stop criterion' for architects that allows them to provide just enough architecture. This definition points primarily at what the things are that an architecture is concerned *about*: "*its components, their relationships to each other and to the environment, and the principles guiding its design and evolution*". The risk is that inexperienced (and method obeying) architects loose themselves in meticulous designs of the future enterprise. The reference to "*the fundamental organization*" only implicitly refers to the purpose for having an architecture, i.e., understanding or expressing the fundamental organisation of a system. But why? And what part of *organisation* is to be regarded as *fundamental*? This is of course dependent on the *purpose* for which the architecture (description) is created. The more recent ISO (2011) version of this definition: "*fundamental concepts or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution*", does not remedy this.

In our observation, the focus on completeness indeed quite often results in overly-detailed architecture descriptions, involving long lists of architecture principles, meticulously worked out models for each of the cells from the architecture framework used, etc. This situation triggered the agile software development community to talk about Ambler and Jeffries (2002); Beck et al. (2001); Cockburn (2002); Lankhorst (2012a) "*Big-Design-Up-Front*" (BDUF). Of course, experienced architects knew when to *stop* architecting. However, early architectural approaches did not provide clear guidelines to ensure that architectures stayed *Fit-for-Purpose*, and rather invited architects to be over-complete.

The need to tune an enterprise architecture to the purpose at hand and avoid overly detailed architectures, triggered the authors of Wagter et al. (2001, 2005) to create the DYnamic Enterprise Architecture approach, which incorporates notions such as "*just enough architecture*", resembling the ideas that were also put forward (in parallel) by the agile system development community. The most recent version of TOGAF (The Open Group 2009) also provides indications for different (purpose specific) ways to use its ADM to ensure the resulting architecture descriptions are indeed fit-for-purpose.

Greefhorst and Proper (2011) suggest to make a clear distinction between:
1: The *purpose* that an enterprise architecture serves. For example, to understand (make sense of) the current/past situation of an enterprise in terms of its fundamental properties and concepts, to articulate and motivate (make sense of) a desired future situation in terms of fundamental properties and concepts.
2: The *meaning* of an enterprise architecture as an artefact. For example, to express (for some purpose) the fundamental properties and/or concepts that underly the present structure of an enterprise, or to express the fundamental properties and/or concepts that should inspire, guide, or steer, the evolution towards the future.
3: The *elements* of an enterprise architecture in terms of the typical concepts used to capture this meaning, such as its elements, relationships, and the principles of its design and evolution as mentioned by the IEEE and ISO definitions, which may be captured by means of models and views.

This distinction enables a clear top-down reasoning on the level of detail and completeness needed from an architecture description. Given the purpose of a specific architecture (description), one can identify the desired meaning of the architecture, and following that, the kinds of elements needed to capture/express this meaning. For example, Greefhorst and Proper (2011) focus on using enterprise architecture for the *purpose* to align the enterprise to its essential requirements and ultimately its strategy: "*... the main purpose of an enterprise architecture is to align an enterprise to its essential requirements. As such, it should provide an elaboration of an enterprise's strategy to those properties that are necessary and sufficient to meet these requirements*". Even though it is only normative in nature, the "*necessary and sufficient*" and the reference to the enterprise's strategy provide a (possible) stopping criterion to keep an architecture Fit-for-Purpose (i.e., steering transformations that aim to establish an enterprise's strategy changes).

### 2.5 From a Constructing to a Constraining Perspective

The shift from computer architecture to information systems architecture, and then to enterprise architecture at large, also resulted in an increase of scope of architecture efforts. Where at the start the focus was typically on a limited number of applications in support of an information system, the organisational scope gradually broadened to business-unit wide, then to enterprise wide, or sometimes even to a sector/branch wide scope. At the same time, the potential time-horizon for architectures increased, from focusing on the situation after the next development stage, to mid-term and longer-term planning activities covering several intermediary stages. The shift from Business-to-IT-stack centricity to more overall enterprise coherence also resulted in a wider range of aspects to be covered in an architecture.

The resulting increase in scope and complexity, combined with the Big-Design-Up-Front to Fit-for-Purpose trend as discussed in the previous section, resulted in the awareness that another means was needed next to the traditional architecture descriptions involving the enterprise's construction in terms of actual building blocks (value exchanges, transactions, business processes, actors, objects, roles, collaborations, etc). This resulted in a strengthening of the role of *architecture principles* as a way to translate an enterprise's strategic intentions to more specific directing/guiding statements, without immediately 'jumping' to the use of actual building blocks of an actual (high level) design. Several architecture approaches indeed position architecture principles as an important element of enterprise architecture (Beijer and De Klerk 2010; Davenport et al. 1989; Op 't Land et al. 2008; Richardson et al. 1990; Tapscott and Caston 1993; The Open Group 2009; Wagter et al. 2005; Wout et al. 2010), while some authors even go as far as to position principles as being the essence of architecture (Dietz 2008; Fehskens 2010; Hammer & Company 1986; Hoogervorst 2009). In our view, the challenges of dealing with increased scope and complexity really emancipated the role of principles as ways to constrain design space.

Fundamentally, we can see a shift from considering an architecture as being primarily concerned with *constructing* the (high level) design of an enterprise in terms of building blocks to being concerned with *constraining* the space of allowable/desirable constructions. A prime example of an architecture from a *constraining* point of view is the NORA (Nederlandse Overheid Referentie Architectuur (NORA) 2012) reference architecture for the Dutch government. It focuses primarily on architecture principles that should be applied in the elaboration of more specific architectures and designs.

It is important to note that the distinction between *constructing* an assembly of building blocks and *constraining* the set of possible assemblies to an allowable/desirable subset, is orthogonal to the *deontic modality*[2] of an architectural description.

[2] See for example http://en.wikipedia.org/wiki/Deontic_modality

This refers to the question if the architectural description is, for example, intended to be a suggestion (*could*), guidance (*advisable*), indicative (*should*), or a pure directive (*must*).

### 2.6 From Building to Integrating

Another trend also resulted in a similar shift towards to the constraining of design space. Instead of developing their own software, most organisations today use packaged solutions, cloud services and other pre-defined solutions to support large parts of their business activities. These solutions may be configured with the organisation's business rules, business processes, information models, etc., but they inherently limit the design freedom of the architect. The upside, of course, is in the common gains of re-use: lowering costs and risks, and speeding up development.

This trend, combined with the growing scope and complexity outlined in the previous section, also leads to a growing emphasis on the integration of various business processes and IT components, within and across organisations. Anyone who has spent some time in a large organisation will recognise that the most common and at the same time most pernicious problems in architecture are at these integration points. The service-oriented architecture (SOA) paradigm Erl 2005 was an important attempt to alleviate this problem, but has not been the panacea that it was once thought to be.

This shift towards integration also influences the design and development process. Whereas in the past, a large system was often designed in one go and as a single, coherent whole, an integrative approach will need to be more piecemeal and iterative: adding and integrating various components one-by-one.

### 2.7 From One-shot to Iterative Approaches

The agile movement in software development (Ambler and Jeffries 2002; Cockburn 2002) has received much attention over the last two decades. Light-weight, iterative methods have gradually taken over much of the software development community. Since the 1990s, evidence has been mounting that agile ways of working, using short iterations and close customer contact, have a higher success rate than traditional, waterfall-like methods for software development, at least for many types of software projects. Recent studies provide theoretical and empirical evidence for the effectiveness of agile methods; see for example the extensive overview by Lee and Xia (2010).

The Agile Manifesto values "*responding to change over following a plan*" (Beck et al. 2001). Many proponents of agile methods are opposed to the use of architecture, categorically classifying it as Big-Design-Up-Front. They argue that stakeholders cannot know what they really need and the problem will change anyway before the project is completed, so one cannot provide any useful designs up-front. Moreover, the changing business environment makes stable requirements an illusion to begin with. Hence, complex socio-technical systems cannot be designed solely behind the drawing board.

On the other hand, many architects and managers resist the agile movement, arguing that one should think before planning actions and building systems. They fear a loss of control and claim that all these agile projects will build their own silos, resulting in the same fragmentation of IT landscapes that the architecture discipline promised to fix.

Both positions are misguided about the role of architecture. A well-defined architecture helps in positioning new developments within the context of the existing processes, IT systems, and other assets of an organisation, and in identifying necessary changes. A good architecture and infrastructure is an up-front investment that makes later changes easier, faster and cheaper, and a good architectural practice helps an organisation innovate and change by providing both stability and flexibility (Lankhorst 2012a). But this does not mean that everything should be architected up-front. As addressed in Sect. 2.4 and Sect. 2.5, a good enterprise architecture is not overly detailed and focuses on the essential inspiration and guidance needed to foster enterprise-wide coherence.

Architecture processes in many organisations still give the impression that architects should do all the thinking beforehand and software developers and others can only start their work after the architects are done. Methods like TOGAF's ADM (The Open Group 2009) are also easily interpreted in this way. The measurable success of agile methods and related developments such as continuous delivery (Humble 2010) creates an increasing need for the architecture discipline to follow suit and embrace a more iterative way of working, closely tied to the entire development process and not merely as a starting phase.

The trend towards less detailed and more normative enterprise architecture, as outlined in Sect. 2.4 and Sect. 2.5, matches well with this need for an iterative approach. Agile enterprise architects provide assistance to projects to help them fit within the big picture, while refraining from too much and too detailed guidance. Moreover, as Ciborra (1992) argued, bricolage, emergence and local improvisation, instead of central control and top-down design, may lead to strategic advantages: the bottom-up evolution of socio-technical systems will lead to something that is deeply rooted in an enterprise's organisational culture, and hence much more difficult to imitate by others. Agile enterprise architects leave room for such local, bottom-up improvements and fit these within the larger scheme of things.

## 3 Future trends

In this section we discuss the anticipated future of enterprise architecture in terms of a number of anticipated trends.

### 3.1 From IT to IT

In most enterprises the role of IT started with the 'automation of administrative work'. In modern day organisations, there continues to be a clear role for IT to automate administrative information processing. However, the use of IT has moved far beyond this. In some situations, IT has given rise to new social structures, and business models. Consider, for example, the development of social media, the (acclaimed) role of twitter in time of social unrest, the emergence of on-line music stores, app-stores, music streaming services, etc. The advent of 'big data' (Hurwitz et al. 2013) is expected to drive such developments even further by allowing IT based systems to use statistical data to tune their behaviour to observed and learned trends.

At the same time, IT is becoming firmly embedded in existing technological artefacts. The cars in which we drive now contain more lines of code than typical banking applications do. The next generation of cars will even be able to (partially) do the driving for us. The so-called smart (power) grid, is likely to lead to the 'smartening' of household appliances. Our houses are already being vacuumed by dedicated robots, while in some cases robots even play a role in the care of elderly people (Tamura et al. 2004). The military use of all sorts of drones also spearheads more peaceful applications of such self-reliant devices that can, e.g., perform tasks on behalf of us in hostile or unpleasant environments.

In sum, we argue that we are moving towards smart and more 'sociable' technology that is enabled by computer technology. One might indeed say, from *information* technology to *intelligent* technology, i.e., from IT to IT. When architecting modern day enterprises, one should treat these as (evolving) collectives of human actors and computerised actors, where the latter might operate in a pure software world, or might be embedded/embodied in other forms of (connected) technology. Needless to say, however, that human actors will always need to remain (socially and legally) responsible for the actions of the computerised actors that operate on their behalf.

### 3.2 From Syntax to Semantics

The trend towards an increased scope of integration, described in Sect. 2.6, brings its own set of design issues. Although paradigms such as service orientation promised to facilitate this integration, they function mainly on a syntactic level, providing a stack of interconnection standards for software systems.

When the integration scope grows, the associated semantic problems grow as well. The information shared across organisational borders may be interpreted in ways that were not intended and do not match with the context in which this information originated. The same holds for the behavioural semantics of cross-border business processes. The Semantic Web (W3C Semantic Web Activity 2013) provides some partial solutions, but the premise of its methods is the unification of semantics in a single overarching ontology, basically trying to standardise the meanings of information. It is simply not feasible to build such ontologies for the size and variety of real-world integration problems. Local variety in semantics cannot be avoided or 'standardised away', because of the inevitable loss of meaning this causes.

This problem is exacerbated by the rapidly growing volume, variety and velocity of 'big data' (Hurwitz et al. 2013), as already mentioned in Sect. 3.1. Applying statistical methods will not suffice to create meaningful interpretations. This implies that novel methods are needed for architecting the semantics of information and behaviour, taking into account the variety and context of meaning and the social processes needed to create understanding and agreement at different scales. It is not feasible to provide complete top-down designs for large-scale socio-technical systems, as we have already argued in Sect. 2.7. The shift from building towards integration (Sect. 2.6), also puts more emphasis on the need for semantic interoperability. Different semantic backgrounds in a multi-organisational setting make this even more complicated. We need gradual, iterative approaches for coherent and collaborative design, development and deployment of these socio-technical systems.

### 3.3 From State-thinking to Intervention-thinking

We argue that contemporary approach to architecture 'think' in terms of *as-is* and *to-be* states of the enterprise. Some approaches may indeed go as far as identifying several intermediary stages between *as-is* and *to-be*, e.g., leading to the concept of *transition architecture* in TOGAF (The Open Group 2009) and plateaus in ArchiMate (Iacob et al. 2012; Lankhorst 2012b). What remains common, however, is the focus on several *states* of the (construction of the) enterprise. This state-oriented thinking might have worked well in the past when the focus was on architecting an enterprise's IT support. However, as soon as other other aspects are taken into consideration, the story becomes more complicated.

As soon as non-technological aspects are taken into consideration, this brings about a shift of focus from *technical* systems to *socio-technical* systems involving a mix of human and technological actors. The enterprise and its environment, being socio-technical systems, will evolve out of themselves. People working in an enterprise will make changes to the 'design' of the enterprise, if only to make the 'design' (continue to) work in day-to-day practise. The people making up the organisation, collectively 'author' their enterprise (Taylor and Van Every 2010).

Even without the use of architecture as a planning instrument, there are likely to be a plethora of projects and related efforts that will continuously change the enterprise in response to external and/or internal stimuli. Some of these changes might not even be 'visible' as projects, as they are based on local initiatives taken within the operational processes (i.e., actors switching between a role in the operational capability to the transformation capability).

We argue that a shift is needed from thinking of enterprise transformations as being a change of an enterprise from one state (the *as-is*) to a future state (the *to-be*), but rather as primarily being an intervention in the natural evolution of the enterprise, resulting in a changed course of its evolution towards a presumably more desirable direction. So, from an as-is *trajectory* to a to-be trajectory.

For the focus of an enterprise architecture this would lead to an even stronger emphasis of the *constructing to constraining* trend as discussed in Sect. 2.5, as constraints are more suitable to articulate desired trajectories than specific building blocks. Using, e.g., *architecture principles* enterprises can distinguish between desirable and less desirable directions of its evolution, and from that infer interventions that can be undertaken to drive, or lure, the natural evolution of the enterprise in the desired direction. These interventions might indeed involve (re-)constructions of building blocks of the enterprise.

### 3.4 From Operational Capability to Transformation Capability

In line with the previous trend, an enterprise is likely to evolve continuously. The capabilities needed to change an enterprise are quite different from the capability needed to run its day-to-day business. The latter capabilities of an enterprise can be referred to collectively as its *operational capability*, while the capabilities needed to transform itself are the *transformation capability*. Teece et al. (1997) stress the need for modern day organisations to have a transformation capability that meet its rapidly changing environment, leading to a highly dynamic transformation capability: "*the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments*". Teece et al. (1997) refer to this dynamic transformation capability as "*dynamic capability*".

It is important to realise that the humans involved in an enterprise can play a role towards both the operational capability and the transformation capability simultaneously. For human beings this is actually quite natural. While executing our daily activities, we typically also learn how to do these activities better and/or adapt them to changing needs/circumstances. In these cases, we decide to 'on the fly' innovate our operational capability. In doing so, we (briefly) use our transformation capability. As a consequence, it is advised to regard the operational capability and transformation capability of an enterprise as *aspect systems* and not as *sub systems*.

When considering an enterprise from an architectural perspective, one can of course opt to focus the architecture efforts on one of these capabilities or both. In most cases that we know of, as well as the illustrating case studies discussed in the existing architecture approaches, the focus is on architecting the *operational capability* only. An exception would be enterprises who have created a so-called *development architecture* focusing on the way the enterprise will go about developing new information systems. An example is the development architecture from the Dutch Tax Administration (Achterberg et al. 2000).

Whether an enterprise's architecture effort should focus on the operational capability and/or the transformation capability depends on the enterprise's strategy. For example, in terms of the Discipline of Market Leaders from Treacy and Wiersema (1997), it would be logical for enterprises focusing on:
1: *operational excellence*, that the operational capability requires architecting priority,
2: *product leadership*, that the parts of the transformation capability dealing with product/service innovation require architecting priority,
3: *customer intimacy*, that the parts of the operational capability and the transformation capability that deal with client interaction require architecting priority.

When indeed also architecting the transformation capability, it is again recommendable to realise that the operational and transformation capabilities are *aspect systems*, and that the different actors (be they human or be they technology) can play roles towards both capabilities simultaneously.

In recent work on agile service development (Lankhorst 2012a), it was also argued that an agile services context requires enterprises to move from having only an efficient operational capability to an effective combination of operational and transformation capabilities. One should focus on designing the operational capability in such a way that it lends itself to quick changes within given boundaries and ambitions, while the transformation capability should be designed in such a way that it can use this built in agility of the operational capability to meet anticipated changes in the environment, as well as the ability to take appropriate actions to transform the operational capability when having to meet unanticipated changes (in terms of Teece, it would have to be *dynamic*).

In Lankhorst (2012a) some guidelines are provided on how to balance an architecting effort between the transformation and operational capabilities. However, more research is needed. At the same time, the need for enterprises to be agile, does stress the need to be able to make explicit tradeoffs on how to deal with this agility across the two capabilities.

### 3.5 From Intuition-based to Evidence-based Management

Modern day enterprises need to change in order to survive. At the same time they need to do so in the face of an increasing number of regulations on compliance and transparency. Furthermore, a considerable part of an enterprise's shareholder value is '*tied*' up in the needed transformations. As a consequence, the processes needed to transform the enterprise become a *core* business process themselves, requiring ample management attention.

In addition, due to the increasing amount of shareholder value (and/or taxpayer's money) that is tied up in such transformations, one can expect that the requirements on the transparency with which such decision are made, will increase. Would it not be logical for companies that are listed on the stock market, to also report annually on their ability to transform in an effective way? In other words, not just how well their operational capability is able to earn a revenue for its shareholders, but also how well their transformation capability is able to ensure the continuation of this revenue in a cost-effective way?

In this sense, one can expect that senior management will increasingly be held responsible (by shareholders, tax payers, and ultimately auditors) for their ability to steer and control transformations. Even more, senior management should not only worry about the cost effectiveness of change, but also about governance, risk management, compliance, etc., associated to these transformations. Given the earlier discussion on the purpose of enterprise architecture, and its role for informed governance, it shall not be surprising that we take the point of view that enterprise architecture would indeed provide a means to senior management to take more control over the transformations and the associated decision making on the future of the enterprises for which they are *responsible*. Using enterprise architecture, one can more crisply analyse problems in an existing situation, articulate desired directions (using architecture in a prescriptive way), analyse the costs and benefits of different options (using architecture in a more descriptive way), and guard that transformation projects are indeed moving in the desired direction.

In parallel to this, one can also observe an interesting trend in the field of management. As argued in (Pfeffer and Sutton 2006, 2011), there is an increasing call for evidence-based management instead of (yet not fully replacing) intuition-based management. The authors draw an interesting analogy to the trend in medicine towards evidence-based medicine (Evidence-Based Medicine 2012), which is defined in Sacket et al. (1996) as: "*the conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients.*". If you think that doctors would always base their diagnose on sound evidence and reasoning, then Pfeffer and Sutton 2011 invites us to rethink this.

When considering the promise of evidence-based management, there is indeed a strong analogy to the potential contribution of enterprise architecture. Some early examples of how enterprise architecture can be used for evidence-based management of enterprise transformation can be found in, e.g., Op 't Land (2006, 2007); Op 't Land and Dietz (2008). We indeed argue that enterprise architecture can become a leading mechanism in enabling evidence-based management of transformations. Or rather, the field of enterprise architecture should take upon it as its *mission* to enable evidence-based management of transformations. We explicitly use the word *enable* to stress the fact that it is senior management who have to take the *responsibility* for making decisions based on evidence. It remains their choice not to take that responsibility, and explain to the shareholders, tax payers and auditors, why they did not.

## 4 Redefining Enterprise Architecture

Based on the future trends as identified in the previous section, we will now revisit our understanding of enterprise architecture. In line with the definition provided in Greefhorst and Proper (2011) we regard architecture as essentially being about: "*Those properties of an artefact that are necessary and sufficient to meet its essential requirements*". This view is shared by Fehskens (2008), who defines architecture as "*those properties of a thing and its environment that are necessary and sufficient for it to be fit for purpose for its mission*". The focus on the properties *that matter*, is also what distinguishes architecture from design. It also resonates well with the reference to *fundamental organization* in the original IEEE definition (IEEE 2000) and the reference to *fundamental concepts* in the ISO definition (ISO 2011).

The reference to properties that are necessary and sufficient to meet its *essential requirements* does indeed introduce a strong form of relativity to architecture: *Who/what determines what the essential requirements are?* We argue that these essential requirements follow from the key stakeholders and their core concerns. *What concerns them most about the artefact?* In the case of an enterprise, the essential requirements can be linked directly to the enterprise's (past/current) strategy, next to other core concerns of the key stakeholders (Greefhorst and Proper 2011). As such, we argue that enterprise architecture should first and foremost be about *essential sensemaking* in that it should primarily:
1: make sense of the past and future of the enterprise with regards to the way it has/will meet its *essential requirements* as put forward by its core stakeholders and captured in its strategy,
2: provide clear motivations/rationalisation, in terms of the above essential requirements, as well as, e.g., constraints, of the trade-offs that underly the presence of the elements (e.g., building blocks or architecture principles) included in the architecture.

In line with this, we argue that the *purpose*, *meaning* and *elements* of an enterprise architecture should evolve:
1: Its *purpose* is (i) to understand the current evolution of the enterprise, including its past and its likely future evolution and (ii) formulate, as well as motivation/rationalise, the desired future evolution and the interventions needed to achieve this.
2: Its *meaning* is that it expresses, in relation to the (current) essential requirements: (i) the understanding how the enterprise has evolved so-far, (ii) what the expected natural evolution of the enterprise is and (iii) the desired future evolution of the enterprise and actions needed to change/strengthen its current evolution.
3: Its *elements* will focus on the fundamental

properties that have played a role in its past evolution, as well as its expected/desired future evolution. These properties can be expressed from a *constraining* perspective in terms of architecture principles and/or from a *constructing* perspective in terms of the building blocks of the enterprise.

It is important to note that during the evolution of an enterprise, it is likely that the understanding of what the *essential requirements* are will change. This means that the boundary between what was included in the architecture and what is considered design may also shift over time. For the modelling languages used (be it from a *constructing* or a *constraining* perspective), this means that they should better take a broad perspective focus on enterprise modelling in general, where what is considered to be "architecturally relevant" may shift over time; modelling approaches with a narrow view of what is "proper" architecture may find themselves obsolete before they know it.

## 5 Conclusion

In this position paper we discussed our view on the history, and the potential future evolution, of the field of enterprise architecture. It is our firm belief that enterprise architecture can, and *should*, play a crucial role in enabling senior management of enterprises to take their responsibility in steering, controlling and/or guiding enterprise transformations, based on sensemaking and evidence-based insights. It is certainly one of the driving hypotheses in our work.

We suggest that future research into the enterprise architecture domain should do so from at least three important vantage points, that are also likely to need different types of research methodologies:
1: An *engineering* perspective that focuses on strategies, methods and techniques to provide evidence-based underpinning of the design decisions underlying enterprise architectures (both in the constructing and the constraining sense).
2: A *modelling* perspective focussing the role of the different models, frameworks, modelling languages, model transformations, and associated modelling processes for enterprise architecture.
3: A *sociological* perspective concerned with the role of culture, skills, attitudes, communication, etc, needed/involved during the formulation of an enterprise architecture, as well as in the intervention needed to establish the changes proposed by a future architectural direction.

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# Enterprise Modelling: The Next Steps

*Enterprise modelling is at the core of Information Systems and has been a subject of intensive research for about two decades. While the current state of the art shows signs of modest maturity, research is still facing substantial challenges. On the one hand, they relate to shortcomings of our current knowledge. On the other hand, they are related to opportunities of enterprise modelling that have not been sufficiently addressed so far. This paper presents a personal view of future research on enterprise modelling. It includes requests for solving underestimated problems and proposes additional topics that promise to promote enterprise models as more versatile tools for collaborative problem solving. In addition to that, the paper presents requests for (re-) organising research on enterprise modelling in order to increase the impact of the field.*

## 1 Introduction

It has been a wide-spread conviction for long that the complexity of large information systems recommends the use of models. Information systems are aimed at representing domains through data that is accessible by prospective users. Representing a–factual or aspired–domain cannot be accomplished by modelling it directly. Instead, it comprises a twofold abstraction: We perceive a domain primarily through language, which in turn reflects an abstraction over "objective" features of a domain. At the same time, using an information system requires an interface that corresponds to the language spoken in the targeted domain. Therefore, the construction of information systems recommends the design of *conceptual models*. They do not only promise to reduce complexity by abstracting from ever changing peculiarities of technical infrastructures; they also allow for getting prospective users involved in the analysis and design process. Exploiting the potential of information systems will often require reorganising existing patterns of action—sometimes in a radical way. Therefore, analysis and design of information systems should usually be done conjointly with analysing and designing the organisational action system. The conception of an enterprise model was developed to address this demand. An enterprise model integrates at least one conceptual model of an organisational action system with at least one conceptual model of a corresponding information system. Usually, but not necessarily, the various models that constitute an enterprise model are created with domain-specific modelling languages (DSML). To emphasise that enterprise models are intended to provide a medium both for fostering analysis and design tasks and for communication across traditional professional barriers, the term "multi-perspective enterprise model" has been introduced (Frank 1994). A multi-perspective enterprise model is an enterprise model that emphasises accounting for multiple perspectives. A perspective represents a specific professional background that corresponds to cognitive dispositions, technical languages, specific goals and capabilities of prospective users (Frank 2013b).

In recent years, the term "enterprise architecture" has gained remarkable attention (Buckl et al. 2010; Land et al. 2009; Lankhorst 2005). The differences between enterprise model and enterprise architecture are mainly related to the intended audience. Enterprise modelling is aimed at various groups of stakeholders that are involved in planning, implementing, using and maintaining information systems. Therefore, enterprise models are supposed to offer a variety of corresponding abstractions. These include models that serve as a foundation of software development. Therefore, the development of respective DSML is a particular characteristic of enterprise modelling. Different from that, enterprise architecture mainly targets IT management. Therefore, it puts less emphasis on the specification of DSML. Nevertheless, there is no fundamental difference between both approaches. Instead, the abstractions used in enterprise architectures can be seen as an integral part of more comprehensive enterprise models. In Information Systems, enterprise modelling has been a pivotal field of research that has evolved over a period of more than 20 years (CIMOSA: Open system architecture for CIM 1993; Ferstl and Sinz 1998; Group 2009; Scheer 1992; Zachman 1987). It has produced various modelling frameworks, DSML as well as corresponding tools. The field has achieved a remarkable degree of maturity which is indicated by the fact that enterprise modelling is part of many IS curricula—even though to different extent. Nevertheless, there is still need for further research to exploit the potential of enterprise modelling. In this paper I will point at relevant shortcomings of the current state of the art in order identify core elements of a future research agenda.

## 2 The Need for More Context

At the beginning, approaches to enterprise modelling were mainly focussed on developing high-level frameworks to provide a common structure or architecture of an enterprise and its information system (CIMOSA: Open system architecture for CIM 1993; Scheer 1992; Zachman 1987). Apart from using general purpose modelling languages (GPML) like the ERM and the UML, the development of DSML was mainly aimed at business process modelling. Later, DSML were created for modelling strategies, organisational structures or generic resources. In recent years, some approaches have evolved that are aimed at DSML for modelling IT infrastructures and IT architectures. This focus is remarkable for two reasons. At first, it represents a renunciation of the original approach to enterprise modelling, which was aimed at developing information systems from scratch. With respect to the complexity of today's IT infrastructures and the fact that most organisations will not develop substantial parts of their information system on their own anymore, this additional focus is certainly reasonable. Secondly, it is not only aimed at supporting the design of IT infrastructures that are in line with the corporate action system, but also at providing an instrument for IT management. Figure 1 illustrates the representation of an enterprise model through a set of interrelated diagrams that correspond to the current state of the art. To ensure integration, the partial models that are represented by the diagrams should be created with modelling languages that were specified with the same meta modelling language and that share common concepts (Frank 2011).

While the abstractions covered by today's enterprise modelling methods arguably represent relevant perspectives on an enterprise, a comprehensive representation of all aspects that may be relevant for analysing, designing and managing a company together with its information system requires accounting for more context. While such a demand may look like an exaggeration to some, it is actually the consequent continuation of current practice: All professional activities in a company are characterised by the use of conceptual abstractions, i.e., by a specific technical terminology and corresponding *language games*. Reconstructing these terminologies through additional DSML would not only enable further use scenarios, it would also enrich existing models with additional context. Context does not only refer to the topics that are represented in an enterprise model. It also refers to the context in which the development and use of models occur. On the one hand, this kind of context includes specific methods for enterprise modelling. On the other hand, it refers to organisational and managerial arrangements to foster an adequate handling of enterprise models.

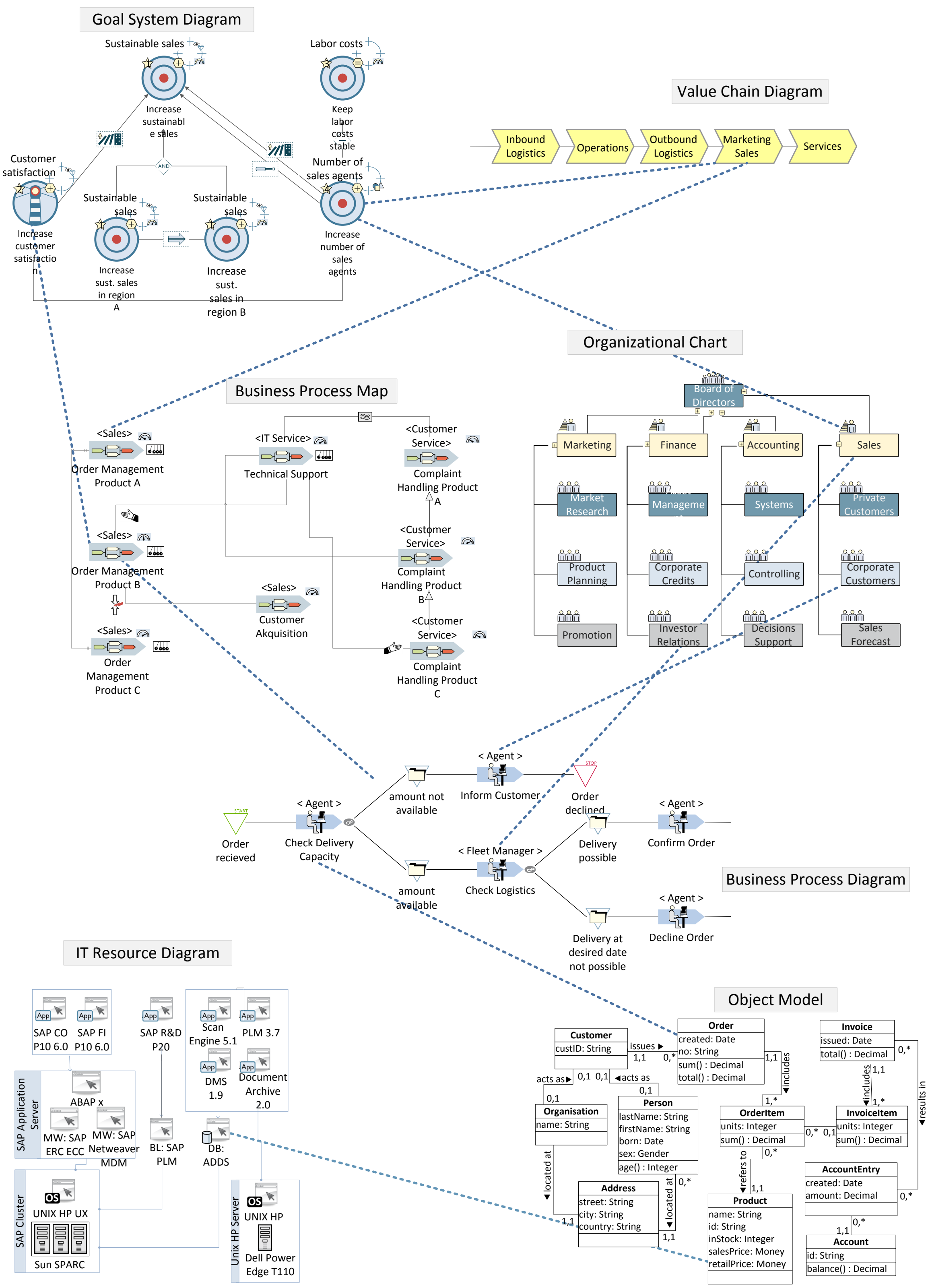


*Figure 1: Diagrams Representing Example Enterprise Model*

### 2.1 Further Modelling Topics

The variety of topics that are handled in enterprises is enormous. Among those that have not been sufficiently addressed in enterprise modelling are products, production processes, projects, markets and logistic. While product modelling is an issue on its own, integrating product models with enterprise models makes sense for various reasons. Products can be very complex and may demand for quick adaptations. At the same time, developing, producing and handling products relates to various aspects of an enterprise that are usually part of an enterprise model: goals, business processes, organisational units or software systems. More and more, products comprise software or are constituted by software. In addition to that products are often bundled—with services and/or other products. Therefore, integrating product models with enterprise models would enable additional analysis scenarios such as checking the effect of changing a product on required skills and on business processes. There are numerous approaches to model production processes. They aim at developing algorithms and approximation procedures for production planning, process scheduling and process control. Integrating respective models with enterprise models will often be not trivial, because they are based on different modelling paradigms. At the same time, including elaborate models of production processes in enterprise models promises various advantages, such as supporting the conjoint analysis of production processes and related business processes or generating software for controlling production processes from respective models. In an increasing number of organisations, projects play a key role. Integrating project models with enterprise models would support project management by providing meaningful links to organisational resources. Also, project modelling could benefit from existing approaches to business process modelling and would allow to take advantage of similarities between projects. Markets have not been part of enterprise models for an apparent reason: They are outside of an enterprise and are usually not subject of design processes. Nevertheless, markets are of crucial importance for successful action in an enterprise. Furthermore, markets are getting more complex and contingent: Often, they expand on an international scale and may be very dynamic in the sense that products are displaced by innovations or that customer preferences change quickly. Therefore, integrating models of markets with enterprise models promises to gain a more differentiated understanding of relevant market forces and to develop a better foundation for decision making. Similar to production processes, logistic networks have been subject of optimisation efforts for long. The respective models, often designed to satisfy the requirements of Operations Research methods, are mainly focussed on optimisation with respect to certain goals. Integrating the respective modelling concepts with languages for enterprise modelling would enable to enrich both enterprise models and logistic models with more relevant context.

In addition to traditional topics, organisations are confronted with new phenomena that may demand for appropriate action. They include social networks, virtual enterprises, nomad employees and many more. Extending enterprise models with models of these phenomena would foster analysing and handling them. This would, however, require new modelling concepts. Finally, enterprise models can be supplemented with concepts that are related to important further aspects of managerial decision making. These include accounting concepts, e.g., specialised cost and benefit concepts, concepts to design and analyse indicator systems (Strecker et al. 2012) as well as concepts for modelling organisational knowledge. Adding these concepts would make enterprise models and corresponding tools a versatile instrument for management—both on the operational and strategic level. At the same time, it could serve as a valuable extension of enterprise software systems (see Sect. 4.1).

*Request*: To make enterprise models a versatile tool for supporting professional action in organisations, research needs to widen the scope of modelling by adding further topics that also comprise concepts to support managerial decision making.

## 2.2 Method Construction

Modelling languages are an important foundation of enterprise modelling, since they provide a purposeful structuring of a domain. However, they are not sufficient for designing and using enterprise models. In addition to languages, there is need for processes that guide the purposeful development, interpretation and use of respective models. In other words: There is need for *modelling methods*. Due to the diversity of projects that can benefit from conceptual models, it is evident that a given set of modelling methods cannot not fit all demands—except for the price of oversimplification. This insight shifted the focus on approaches that guide the development of customised methods. The only chance to provide support for the conceptualisation of a range of methods is to increase the level of abstraction by searching for essential characteristics shared by all modelling methods. Against this background, the emergence of method engineering as a new field of research is a reasonable consequence in two respects: First, it is aimed at rich abstractions that cover a wide range of modelling projects. Second, it makes use of the same paradigm that it suggests for the field of conceptual modelling, too: The construction of particular methods should follow an engineering approach, which—among other things—recommends accounting for linguistic rigour, consistency and coherence as well as for the development of supportive tools. During the last 15 years, a plethora of method engineering approaches—originating mostly in Requirements Engineering and Software Engineering—has evolved (Brinkkemper 1996; Ralyté et al. 2005, 2007). For an overview see Henderson-Sellers and Ralyté (2010). Some emphasise the construction of methods from reusable elements, others focus on the instantiation of methods from metamodels, while further approaches are based on a combination of composition and instantiation. It seems that the field has reached a stage of moderate maturity, which is also indicated by the specification of a respective ISO standard (ISO/IEC 2007).

Nevertheless, there are some aspects that have been widely neglected so far. At first, current approaches to method engineering are mostly generic in the sense that they are not restricted to particular domains, nor do they account for the peculiarities of enterprise models. That leaves prospective developers and users of enterprise models with the demanding task of adapting generic concepts to the idiosyncrasies of particular organisations. Second, current approaches to method engineering focus on the design of process models and take the modelling language as given. However, the diversity of topics that can be reasonable subjects of enterprise models may also require to adapt or even create modelling languages. While a number of tools support the specification of DSML and the realisation of corresponding model editors, prospective users can expect only little guidance with designing a language that fits its purpose. At the same time the design of DSML is especially demanding. Often, prospective users will not have an idea of what they might expect from a DSML. As a consequence, requirements analysis is a remarkable challenge. In addition to that, design conflicts need to be handled. Also, the creation of the concrete syntax requires a specific competence that many language designers do not have. Therefore, there is need for substantiated guidance to reduce the risk of poorly designed modelling languages. Currently, there are only few approaches that offer respective support (Frank 2013a; Moody 2009). Finally, method engineering is often based on two assumptions: First, a method is an artefact that is created through an engineering act. Second, applying the method appropriately is pivotal for successful action. However, with respect to successfully using a method, it is not sufficient to restrict it to its explicit definition, i.e., to take a mere technical perspective. This is for two interrelated reasons. First, a method will usually not be based on a pure formal specification. Instead, its conceptual and theoretical foundation as well as the process description require interpretations that produce some degree of shared understanding. Second, for a method to work, it has to become an accepted orientation for individual and collaborative action. To summarise both aspects: A method needs to make sense. From this point of view, a method can be regarded as a social construction that reflects established patterns of professional action, ideas of professional values and aesthetics, organisational culture, common beliefs as well as individual interests. Against this background, we can distinguish between a method as a linguistic artefact, stressing a technical view, and a method as an actual practice, stressing a more pragmatic or organisational view. Therefore I intentionally avoid the term "method engineering" and speak of "method construction" instead. This is to express that a method is also constructed by those who use it, because it is shaped by actual interpretations and actions. A method as an artefact could be regarded as input or stimulus to trigger such a process. While for analytical reasons it may be useful to focus on methods mainly as linguistic artefacts, such a restricted view is certainly not sufficient with respect to a pragmatic objective such as improving efficiency and quality of collaborative problem solving in organisations. The benefit of methods for enterprise modelling will not only depend on the qualification of the involved stakeholders, but also on certain aspects of the respective corporate culture. It makes a clear difference, whether conceptual models are regarded as corporate assets or as cost drivers with dubious outcome.

*Request*: To promote the beneficial development and use of enterprise models it is required to support the construction of respective modelling methods that account for both, the conceptual foundation of designing/customising methods as linguistic artefacts and additional organisational/managerial measures that promote the appropriate use of methods in practice.

## 3 The Need for More (Re) Use

The remarkable effort that is required to build elaborate enterprise models makes reuse of models and modelling concepts a pivotal issue for achieving higher productivity. At the same time, reuse can also contribute to model quality, if reusable artefacts are designed and evaluated with specific care. In addition to that reusable concepts can serve to foster integration of those components that share them. Approaches to promote reuse have been on the research agenda for long. The idea of reference enterprise models seems to be especially attractive. However, so far, reuse of enterprise modelling artefacts remained on a modest level (Fettke and Loos 2007). There are various reasons that contributed to this unsatisfactory situation. Two especially important reasons are related to modelling languages. On the one hand, current languages for enterprise modelling lack concepts that enable reuse. On the other hand, the design of reusable DSML is facing a substantial challenge.

### 3.1 The Lack of Abstraction in Process Modelling

Taken the fact that business process modelling has been a research subject for long, it seems surprising that respective modelling languages are rather primitive in the sense that they do not allow for powerful abstractions. As a consequence, reuse of business process models remains on a dramatically poor level. Since business process models play a pivotal role within enterprise models, this is a serious shortcoming. The following scenario illustrates the problem. A company comprises a few tens of business process types including a core order management process type. A process type includes activity types. Various process types share similar activity types. Now two more specific order management process types need to be implemented. For this purpose,

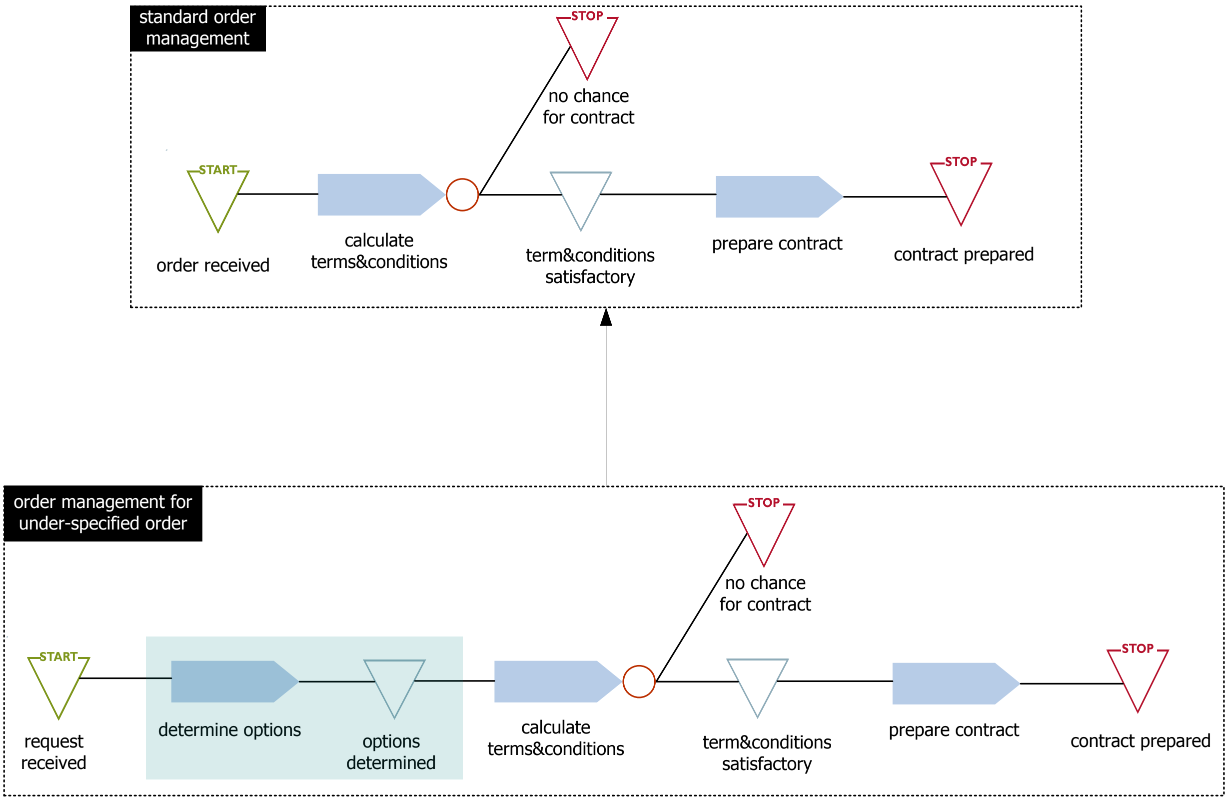


*Figure 2: Example of extending a business process type*

it would be most helpful to specialise the existing order management process type.

This would not only allow reusing the respective model and corresponding software implementations, it would also promote safe and convenient maintenance: Future changes of the core process type would be immediately effective in the specialised types, too. To satisfy the demand for integrity, a respective concept of process specialisation would have to satisfy the substitutability constraint: Every instance of a process type can act as an instance of the corresponding super process type without causing harm (Liskov and Wing 1994). The substitutability constraint is satisfied, if the extensions defined for specialised concepts are monotonic. This can be accomplished fairly easy for static abstractions. However, for dynamic abstractions such as business process models adding further activity or event types cannot be monotonic, because it will always effect the original control flow (Frank 2012). The example in Fig. 2 illustrates this problem.

There are a few approaches in Software Engineering and process modelling which are aimed at a relaxed conception of specialisation of behaviour (Schrefl and Stumptner 2002) or of "workflow inheritance" (Aalst and Basten 2002). Other approaches focus on analysing structural similarities of control flows to promote reuse through process variants (Koschmider and Oberweis 2007). However, the restrictions these approaches imply remain unsatisfactory (Frank 2012). At the same time, the still growing relevance of efficiently creating and maintaining business process models demands for abstractions that allow taking advantage of similarities.

*Request*: Future research should aim at concepts of relaxed process specialisation—which may be combined with instantiation—that promote reuse without unacceptable restrictions.

While the lack of a sound concept of process specialisation creates a serious problem, the current state of business process modelling is even more dreary. The above scenario would suggest to reuse an activity type that was defined already for a certain business process type in a new process type. However, this is not possible: Every business process type has to be designed from scratch using the basic concepts provided by today's process modelling languages. Hence, an activity such as "prepare contract" cannot be specified as a reusable type. Instead it is yet another instance of a basic (meta) type like "activity" or "automated activity" that is distinguished from other primarily through its label. There are approaches that focus on analysing labels in order to detect similar activity types (Dijkman et al. 2011). However, their contribution to reuse is limited: Instead of removing the mess, they try coping with it.

*Request*: There is need for extending business process modelling languages and tools with the possibility to define and reuse activity and event types.

This request is not easy to satisfy. An activity type is not only defined by its internal structure and behaviour, but also by its context such as the event that triggers it or the events it produces. Reuse will be possible only, if the context can be adapted to some extent. Therefore, the required concept of an activity type—and of an event type respectively—must abstract from the context without compromising reusability too much.

### 3.2 The Essential Conflict of Designing DSML

DSML are characterised by convincing advantages (Kelly and Tolvanen 2008; Kleppe 2009; Völter 2013). By providing domain-specific concepts, they promote modelling (and programming) productivity: Modellers are not forced anymore to reconstruct domain-level concepts from generic concepts such as "entity" or "attribute". At the same time, DSML foster model integrity, because they prevent the creation of inconsistent models to a certain extent. By featuring a domain-specific concrete syntax, they also promote model comprehensibility. Against this background, it does not come as a surprise that DSML are regarded by many as the silver bullet of conceptual modelling and model-driven software development. However, their construction is facing a dilemma. The more a DSML is tuned to a specific domain, the better is its contribution to productivity and integrity. However, the more specific a DSML is, the more unlikely it can be used in a wide range of particular domains. Figure 3 illustrates the conflicting effects of semantics on range of reuse and productivity.

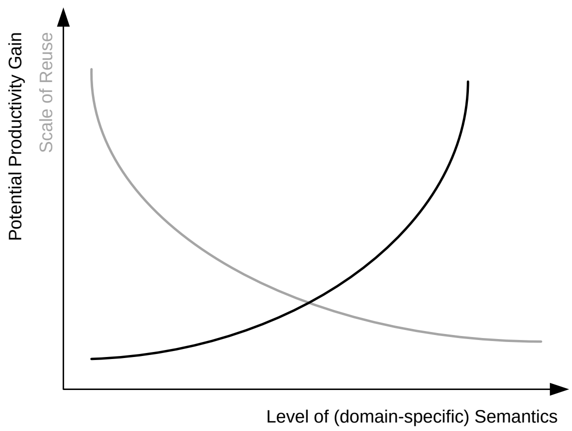


*Figure 3: DSML: Illustration of Essential Design Conflict*

Some authors suggest to design DSML to the needs of particular organisations or even projects only (Kelly and Tolvanen 2008; Völter 2013). This recommendation is based on two assumptions. First, the variety of organisations would not allow for powerful DSML that fit all individual requirements. Second, there is no need for further reuse, because creating and using a DSML in one particular project will usually pay off already. Even though both assumptions may be valid to a certain extent, they are hardly convincing. There may be remarkable differences between organisational actions systems and corresponding terminologies. However, it would be a sign of epistemological defeatism to deny the chance of finding substantial commonalities. Furthermore, it can be assumed that actual variety is also a result of in part arbitrary processes of organisational evolution, i.e., it is not a reflection of inevitable differences. Also, there is evidence that technical languages work in a wide range of organisations of a certain kind: The terminology used in textbooks will often fit an entire industry in the sense that it provides a respected linguistic structure and serves as as common reference for professionals. Nevertheless, there are organisation-specific adaptations of textbook terminology. They include extensions, refinements and modifications, some of which may be questionable. The argument that a DSML will already pay off in single use scenarios is fine, but it could still be much more profitable, since a wider range of reuse would allow for much better economies of scale. Therefore, it would be beneficial to create hierarchies of DSML, where more specific ones are extensions and/or instantiations of more general DSML.

*Request*: Research on DSML should aim at hierarchies of languages to enable both a wide range of reuse and customised languages for narrow domains.

Figure 4 illustrates the idea of providing modelling languages on different classification layers. The highest level ("universal DSML") corresponds to textbook terminology. The concepts on this level should be applicable to a wide range of organisations, hence, promote economies of scale. The universal DSML should be designed by experts that possess deep knowledge about the general domain as well as rich experience with designing DSML. "Local" DSML represent more specific technical languages for organisation modelling that apply to a few organisations or to one only. They are designed by organisation analysts that are familiar with the respective domain. These local DSML that feature a graphical notation much like the universal DSML can be used by authorised managers to specify particular organisational settings. The example also shows that there are cases where it makes sense to create models that include concepts on the M0 level.

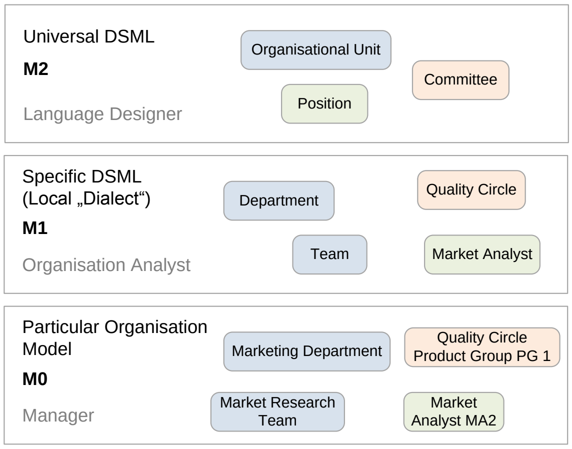


*Figure 4: Illustration of multi-level modelling languages*

Designing such language systems and corresponding tools is far from trivial. It requires giving up prevalent architectures of modelling languages that feature a given set of classification layers (for respective approaches see Atkinson et al. (2009); Clark et al. (2008); Simonyi et al. (2006). Instead, recursive language models such as the "golden braid" architecture are more promising—and more demanding at the same time, because they are not supported by most of today's development environments. Apart from that, designing languages for enterprise modelling should account for a further issue. Current DSML are usually specified with metamodels. This is for a good reason: On the one hand, this kind of specification corresponds to a paradigm the modelling community is familiar with. On the other hand, it fosters the construction of corresponding tools, because a metamodel can be used as a conceptual foundation of a respective modelling tool. The semantics of DSML, e.g., the semantics of specialisation concepts, is usually based on the semantics of prevalent programming languages to facilitate the transformation of models into code. However, there are other language paradigms and specification styles that might enrich enterprise models. For instance, models designed with logic-based languages allow for deduction could enable more sophisticated approaches to analysing enterprise models. Since the semantics of respective languages, which are typically found in Artificial Intelligence, is different from that of DSML used for enterprise modelling today, integrating them into enterprise modelling environments is a demanding task.

## 4 The Need for Run-Time Use

Originally, enterprise models like most other conceptual models were intended for supporting the creation of information systems only. However, it is obvious that they should be beneficial during the entire life cycle of an information system. On a more generic level, this issue is addressed by research on “models at runtime” (Blair et al. 2009). Multi-perspective enterprise models provide abstractions of the enterprise that support decision making and other managerial tasks. Also, they can help people in organisations to develop a deeper understanding of the action system, i.e., how their work is integrated into a bigger picture. In addition to that, enterprise models can enable users to develop a better understanding of the information system and its interplay with organisational patterns of action.

### 4.1 Integrating Enterprise Models with Enterprise Systems

In an ideal case, an enterprise modelling environment would be integrated and synchronised with a corresponding enterprise (software) system. On the one hand, this would enrich enterprise systems not only with their conceptual foundation, but also with a representation of the context they are supposed to operate in. On the other hand, enterprise models would be supplemented with corresponding instance populations.

This would enable users to navigate from concepts on various classification levels to instances—et vice versa. The following scenario illustrates the benefit of drilling down from an enterprise model to instances. A department manager who is new to a firm wants to get a better understanding of the way business is done. For this purpose, he could browse a graphical representation of the corporate business process map, which shows all business process types, their interrelationships and key performance indicators at a glance. He could then select a business process type he is interested in, study the model that describes its execution and demand for further aggregate data that characterises it, such as the number of instances per month, average revenues etc. Also, he could select specific analysis views, e.g., a view that associates a selected business process type with the IT resources it requires. If he was interested in one particular business process type, he could view the corresponding model. Then, he could leave the conceptual level and ask for the list of currently active business processes of this type and inspect the state of the instances he is interested in. In addition to that, advanced users could modify the enterprise system by changing the enterprise model. The DSML, an enterprise model is created with would help preventing arbitrary modifications and hence contribute to system integrity. An outline of a respective system, referred to as “self-referential enterprise system” is presented in (Frank and Strecker 2009). Figure 5 illustrates the idea of integrating enterprise systems with enterprise modelling environments.

Such a system would allow realising the vision of interactive models propagated by Krogstie (2007, p. 306): “The use of interactive models is about discovering, externalising, capturing, expressing, representing, sharing and managing enterprise knowledge.” In other words: It would be a contribution to empowering people who work in and interact with organisations. The realisation of self-referential enterprise systems does not only require developing further DSML, but also redesigning enterprise software systems.

*Request*: To further exploit the potential of both enterprise software systems and enterprise modelling environments, research should aim at developing the foundations for integrating both kind of systems into a versatile tool for managing and adapting an organisation and its information system.

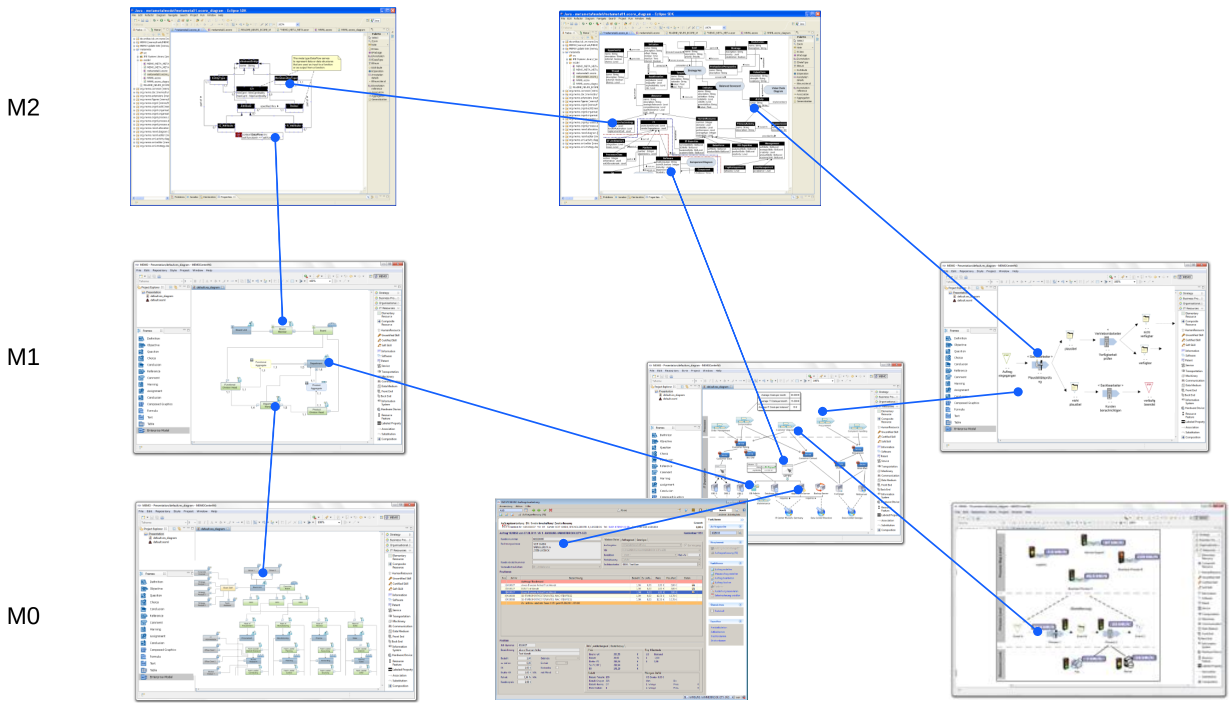


*Figure 5: Navigating an enterprise model and corresponding instances*

## 4.2 Deficiencies of Prevalent Programming Languages

The integration of enterprise modelling environments and enterprise systems does not only require research on enterprise models and their representation. It also demands for system architectures that cannot be satisfactorily accomplished with prevalent programming languages. Integration implies common representations of shared concepts. In today's modelling environments, conceptual models are usually represented by objects on the M0 level—even though they belong to the M1 or even a higher level. Overloading the M0 level happens for a good reason: Prevalent programming languages are restricted to the dichotomy of objects and classes. Hence, there are no meta classes that were required to specify classes—and that would allow treating classes as objects, too. Therefore, a common representation of classes in both systems is not possible. Instead, the only way to associate a modelling environment with a corresponding enterprise system would be to generate code, i.e., classes in the enterprise system, from objects in the enterprise modelling environment. As a consequence, one would have to deal with the notorious problem of synchronising models and code. Figure 6 illustrates how the M0 layer of modelling tools is overloaded and that concepts in modelling tools are located on a classification layer that is different from that of corresponding concepts in an associated enterprise information system.

Recent developments in research on programming language has produced (meta) programming languages that were designed for creating domain-specific programming languages. Languages like XMF (Clark and Willans 2012; Clark et al. 2008) are especially promising, since they allow for an arbitrary number of classification levels, which enables a common representation of models and respective code. Hence, modifying an enterprise model implies modifying the respective part of the enterprise software simultaneously.

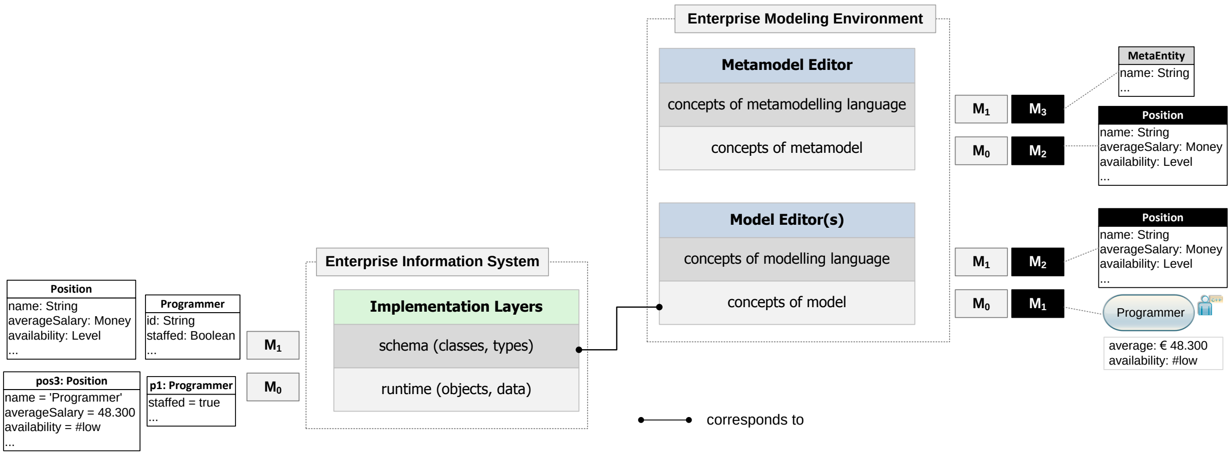


*Figure 6: Mismatch of Classification Levels*

*Request*: To advance the state of current modelling environments, research needs to focus on tools that overcome the limitations of current programming languages.

## 5 The Need for Collaboration

Extending the scope of enterprise models and developing them to an omnipresent representation of organisations requires an amount of research and development that cannot be carried out by the current enterprise modelling community alone. To advance the field, there is need for cross-disciplinary collaboration and for accumulating resources.

### 5.1 The Importance of Bundling Resources

The development of comprehensive enterprise models will overburden most organisations. This is the case, too, for respective DSML. Reference enterprise models and wide-spread DSML are suited to effectively address this problem. Furthermore they would provide a foundation for cross-organisational integration of action systems and information systems, which could enable a tremendous boost of productivity. At the same time, the development of reference artefacts that combine a descriptive and a prescriptive approach constitute an attractive research goal: It is characteristic for research to abstract from single cases and aim at constructions that work for an entire class of cases. Furthermore, applied research is motivated by improving existing practice with respect to certain goals. Unfortunately, the development of reference enterprise models and corresponding languages and tools requires resources that are not available to a single research institute. Furthermore, establishing and disseminating them in practice depends on economic and political aspects that are beyond the abilities and intentions of academics. Against the background, it is obvious that there is need to bundle resources of research institutions. At the same time, it is necessary to get vendors of enterprise software and prospective users involved. On the one hand, they need to be involved to support requirements analysis. On the other hand, using reference artefacts in practice is the only way to promote their dissemination. Unfortunately, there are serious obstacles that impede both bundling of research resources and involvement of companies. Research is based on competition and the idea of scientific progress. Collaboration of research institutes implies to give up competition to a large extent. At the same time, for reference artefacts to be beneficial they need to be consolidated—which may jeopardise scientific progress. While there are probably many vendors and client organisations that would be happy to use reference models, most of them will likely be reluctant to participate in respective development projects, since the return on such an investment would be hard to determine. Nevertheless, to promote the benefit of enterprise models, reference artefacts that enable attractive economies of scale are of pivotal relevance.

*Request*: There is need for initiatives to collaboratively develop and disseminate reference artefacts. They need to provide convincing incentives both for academics and practitioners.

One of the prime examples of community-driven collaboration is free and open source software (FOSS). Respective initiatives have successfully promoted collaboration of developers and users. Also, they led to software systems of surprising quality, and, in some cases, to an impressive dissemination. Inspired by the apparent success of some FOSS projects, corresponding "Open Models" initiatives have been proposed (Frank and Strecker 2007) and inspired the creation of open model repositories (France et al. 2007), (www.openmodels.org, www.openmodels.at). While these repositories have triggered remarkable attention, there is still need for more active participation.

### 5.2 Enterprise Models as Object and Promoter of Cross-Disciplinary Collaboration

Enterprise models are aimed at providing a medium to foster communication between stakeholders with different professional background. On the one hand that requires reconstructing technical languages and professional patterns of problem solving. On the other hand it recommends analysing how prospective users react upon the models they are presented with. That includes concepts as well as their designation and (graphical) representation. For using enterprise models effectively, software tools are mandatory. Developing and integrating them with other enterprise software systems creates substantial challenges for Software Engineering or—in other words—interesting research questions. Enterprise modelling is not an end itself. Instead, it is supposed to have a positive impact on a company's economics and competitiveness. However, assessing the costs of creating and maintaining enterprise models, which may include the development of languages and tools, is not a trivial task—and it is similarly challenging to determine the benefits that can be contributed to the deployment of enterprise models. Apart from economic effects, the extensive use of enterprise models within an organisation may have an impact on how people perceive not only their tasks but also the entire organisation. The increase in transparency may have an effect on established patterns of organisational power and may require new approaches to managing organisations. Against this background it is obvious that enterprise modelling involves a wide range of demanding research questions that concern various disciplines. Business and Administration in general is aimed at developing and improving terminologies and methods that are suited to structure and guide purposeful action in enterprises. Various subfields, such as Financial Management, Accounting, Industrial Management, Logistics could contribute to extend and deepen enterprise models. In Psychology, the interaction between cognitive models and external representations is a core research topic. Applied to enterprise modelling this would include the question how conceptual models effect individual and collective decision making. That includes analysing the impact of graphical notations on people's ability to understand complex matters—and the development of guidelines for designing notations that fit certain cognitive styles. Both, from a psychological and a sociological point of view, it would be interesting to analyse how enterprise models effect the social construction of reality, i.e., to what extent people perceive the model as the enterprise and what that means for the way they (inter) act. Assuming that enterprise models may have a substantial effect on an organisation's performance implies challenging research questions for economic studies that are not restricted to enterprise models, but comprise the economics of models and methods in general. Combining research results from various disciplines would not only contribute to advance our knowledge about enterprise models and our ability to use them effectively, it is also suited to enrich the state of the art in the participating disciplines, since it would integrate it with contributions from other fields. Therefore the following request could have a better chance to succeed than yet another call for inter-disciplinary research.

*Request*: Advancing the field of enterprise modelling recommends to establish inter-disciplinary research collaboration.

## 6 Conclusion

In the past, enterprise modelling, though arguably pointing at a core topic of Information Systems, has been subject of a rather small, specialised research community. In Business and Administration it is regarded as too much focussed on technical aspects by some, while some traditionalist colleagues in Computer Science suspect it of lacking formal rigour. However, enterprise modelling is more than analysing and designing information systems—and it is certainly much more than drawing "‘bubbles and arrows”. Enterprise modelling is about conceptualising an important part of the world—as it actually is and as it might be. Hence, it requires knowledge about how people (inter) act in organisations, how information systems infrastructures are built—and the creativity to develop substantial images of attractive future worlds that comprise the purposeful construction and use of information systems. It is about how we perceive the world we live and work in and how we think about it and might change it—alone and together with others. In addition to supporting collaboration between stakeholders with different professional backgrounds in organisations, enterprise models may also serve as a medium and object of inter-disciplinary research. At the same time, they are suited to foster the exchange between practice and academia, because they allow to integrate more abstract representations of enterprises with more specific ones. Last but not least, enterprise models provide a laboratory for learning, because they convey a solid conceptual foundation of information systems and surrounding action systems—and enable students to navigate through an enterprise on different levels of detail and abstraction. With respect to such a wide and deep conception of enterprise modelling it is important not only to identify relevant steps of future research, but also to spread the word and encourage others to participate in joint projects. Further developing the field also requires to put more emphasis on assessing model artefacts. On the one hand that comprises the development of pragmatic criteria to evaluate models and modelling languages with respect to an intended practical use. On the other hand, it relates to assessing the epistemological quality of model artefacts as research results. Developing and applying respective criteria is an important prerequisite of scientific competition and progress.

In this paper I gave a personal account of the topics we should address in the next years to advance our field. It is needless to say that other relevant topics exist, too. I would hope that the requests presented in this paper contribute to a discourse on our future research agenda.

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José Tribolet and Pedro Sousa and Artur Caetano

# The Role of Enterprise Governance and Cartography in Enterprise Engineering

*Enterprise artography is fundamental to govern the transformation processes of an organisation. The artefacts of enterprise cartography represent the structure and dynamics of an organisation from three temporal views: as-was (past), as- is (present), and to-be (future). These views are dynamically generated from a continuous process that collects operational data from an organisation. This paper defines a set of enterprise cartography principles and provides an account of its role in understanding the dynamics of an organisation. The principles are grounded on control theory and are defined as a realisation of the observer and modeller components of the feedback control loop found on dynamic systems. As a result, an organisation can be abstracted as a dynamic system where a network of actors collaborate and produce results that can be depicted using cartographic maps.*

## 1 Introduction

This paper explores the role played by enterprise cartography and enterprise governance within the enterprise engineering discipline. Enterprise governance relates to enterprise transformation since the change of operational processes, resources and business rules define new management boundaries (Hoogervorst 2009). Enterprise architecture contributes to enterprise transformation as it enables modelling the organisation's structure and dynamics along with the underlying restrictions and design principles (Lankhorst 2013; Op't Land 2009). Transformation is often seen as the set of initiatives that change the organisation's domain from the current *as-is* state to an intended *to-be* state. These two states describe organisational variables at different moments in time. The *as-is* state is defined by the variables that changed due to past events, while the *to-be* state specifies an expected state configuration of the organisational variables. Between these two events, the organisation reacts to other events that are triggered by the operation of the transformation processes.

The issues we address in this position paper focus in the ability to observe and govern the organisation during such transition. This is important because during each transformation initiative an organisation has to react to events. Some of these events may be unrelated to the transformation initiative but may impact the transformation process and therefore deviate the organisation from achieving the planned future state.

This paper presents two contributions. The first is defining enterprise cartography as a function of the *observer* and *modeller* roles as defined by the enterprise's dynamic feedback control loop. Enterprise cartography is not associated with the enterprise design, but with the abstraction and representation of the enterprise reality. Although this differentiates enterprise cartography from enterprise architecture, it may be correctly pointed out that cartography is part of enterprise architecture. But given the relevance of cartography to understand the dynamics of the feedback control loop of an organisation, we opted to discuss the concerns of cartography separately from those of enterprise architecture. The second contribution of the paper is stating the empirical principles that ground the design of the cartography process to play the role of the observer and modeller in the enterprise dynamic feedback control loop. Dynamic systems and enterprise governance are described in Sect. 2 and Sect. 3. Section 4 presents enterprise cartography.

## 2 Dynamic Systems

The application of systems theory to systems engineering has been discussed since the 1970s (Eriksson 1997; Moigne 1977). Systems theory relates to organisational systems mainly through the principles of dynamic systems, especially control feedback loops (Abraham et al. 2013; Santos et al. 2008). These concepts can be further combined with classic management theories as a means to clarify how feedback loops interact with different organisational views, such as governance, management, and operations (Fig. 1).

In control theory, the *modeller* presents a system view that specifies its current *as-is* state (Levine 1996). The current state makes possible to estimate a future state of the system in the absence of unexpected events. To handle the potential deviations that occur from such events, control theory introduces the concept of *controller*. The *controller* analyses the continuous stream of events and modifies the system's controllable variables as a means of keeping the system behaving as planned (Fig. 2). This is similar to the control of a physical body moving toward a target: the modeller determines the current position and speed of the object and feeds it to the controller; if an unexpected event occurs, then the controller corrects the movement of the object by applying the necessary forces and thereby ensuring that the target is reached.

We argue that the relationships between enterprise governance and enterprise cartography can be established using the principles of dynamic systems feedback control, where cartography plays the aforementioned roles of observer and modeller. These relationships are explained in the next two sections.

## 3 Enterprise Governance

An enterprise is a network of independent actors. Actors collaborate with other actors along time and thus create a dynamic collaborative network. Actors also produce autonomous behaviour that may change the overall state of the system. Actors can be classified as*carbon-based actors*, i.e. humans, and *silicon-based actors*, i.e. computers. This network runs within a domain where the independent actors behave towards a future state of affairs, and thus produce events, some of which may be unexpected. Therefore, all enterprise domain state changes are a consequence of the individual behaviour of an actor or of the composite behaviour that derives from the actor collaborations. These collaborations may occur between actors that are enclosed by the organisation's boundary, or between an actor that is external to the organisation and one internal actor. So, the behaviour of an enterprise "is" a result of what "it does". An enterprise can therefore be regarded as a large "bionic" distributed network of carbon-based and silicon-based actors that are continuously interacting and producing behaviour.

The current technological advances make possible near real-time, transparent and ubiquitous interaction between people and systems. As such, the boundary between manual, semi-automated and even some automated operations becomes blurred. This means that the actions performed by people cannot be easily separated from those of people supported by a network of computers, and from those of networks of computers. These collaborations can be abstracted as the result of a single network that operates in (near) real-time. The actors that interact within this network act autonomously.

Autonomous behaviour is evident from how a person acts within an organisation since the state change produced by a human actor can only be observed *after* the action is concluded. But the same phenomenon is also observed on information systems because one can only assert what

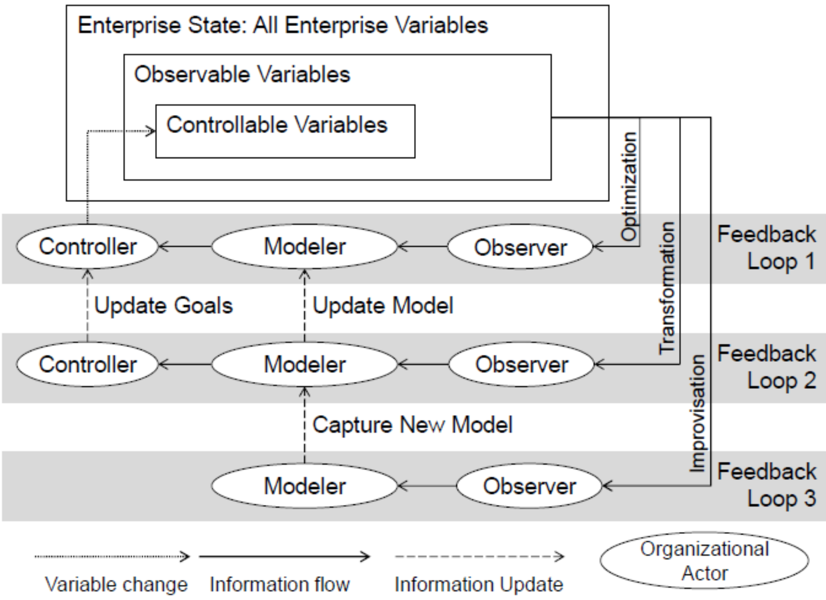


*Figure 1: Organisational views and feedback loop, adapted from (Abraham et al. 2013).*

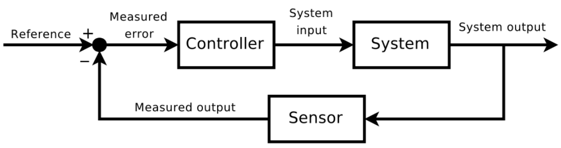


*Figure 2: A single-input, single-output feedback loop.*

a computer actor has produced after the actual action is performed. The degree of predictability of automated computer actions is potentially higher than that of humans. But achieving certainty is not feasible due to a number of factors. On the one hand, a system may not behave as expected due to faults or failures. And even in the absence of faults of failures, the system may be misaligned with the business. On the other hand, the interaction between multiple systems can produce emergent behaviour, meaning that the overall behaviour of the system may not be the linear sum of each individual behaviour unit. As a result, there is a potential gap between the results that derive from planned actions and the actual results. This makes it impossible to fully estimate the outcome of the interactions in such a network.

This reasoning supports the conclusion that enterprises are dynamic systems. Enterprises are actually a system of systems, composed of and part of other dynamic systems. As such, there is an opportunity to try to understand an enterprise as a complex system through the lenses of systems theory, in particular through the body of knowledge of systems theory and dynamic systems control. However, this application must always consider the intrinsic bionic nature of an enterprise, as people cannot be dissociated from its essence. We defend that all this body of knowledge is directly applicable to enterprises through enterprise engineering. The fundamental purpose of engineering is to provide humans with artefacts that augment their individual and collective capability to deal with specific situations. Engineering helps humans to understand reality and to pro-actively and purposefully transform it as idealised by individual and collective goals. This is the primary purpose of enterprise engineering (Dietz et al. 2013).

How do systems theory and dynamic systems control relate to enterprise engineering? Well, let us start with the “bionic state machine” metaphor presented earlier. According to systems theory, this model can be abstracted as two separate subsystems: a *feed-forward action system*, which is combinatorial in nature and transforms inputs into outputs, and a *feed-back cybernetic system*, which uses as input the state observations and results provided by the feed-forward action system. The feed-back system uses this information to continuous estimate the current state of the system. This is accomplished by contextualising the observations, i.e. by situating the observations into the semantic model of the system. Based on these observations, the feed-back cybernetic system then decides on the actions that all the actors of the system must perform in order to keep the system on a trajectory that achieves its goals. This process is continuously performed. These concepts have been extensively applied to most engineering areas for at least half a century (Andrei 2005).

In this paper we hypothesise that the application of control theory is useful to help understanding enterprise engineering. The next hypothetical principles characterise enterprise governance as a dynamic systems theory problem.

**Principle 1 Actions performed by people are enacted by the *feed-forward action* system**. People play multiple actor roles within an enterprise such as operational, middle management, knowledge work, auditing, advisory, governance or executive roles. If an enterprise is abstracted as a layered system, all these actions occur at the operational layer, where actual operations are performed by actors. People are abstracted as actors playing roles within well specified semantic domains that uniquely define their contexts of individual action and interaction (Caetano et al. 2009; Zacarias et al. 2005). An actor is capable of playing several roles simultaneously.

**Principle 2 A person can be abstracted as a system of systems whenever its actions and interactions occur within the enterprise network**. This means that the roles played by people are subject to the rules of the dynamic systems control model. The actions of a person are the result of a combinatorial procedure: a person observes the world, attempts to contextualise and understand its meaning, and then performs an action. This procedure corresponds to the role of *controller*. By acting as a controller, the person can correct the deviations between the current state and the intended state. As such, to achieve goals an human actor operates his own local feed-back subsystem. These actions do not occur at the operational layer but at an higher layer that plans and controls the operations (Abraham et al. 2013).

**Principle 3 An enterprise is more than the sum of its actors and resources**. Organisational factors such as culture, values, power, and hierarchical structures are elements in defining an enterprise. We abstract these "soft" factors as quality requirements that constrain and parametrise the operating system of an human actor. They are key determinants to the way a human interprets the observations of reality, as well as he reads these observations through his own models of the world, based on which his own sense making operates. These factors have impact on the actions of a human actor since they change how it plays the controller role.

**Principle 4 Enterprise self-awareness requires the specification of the domain of action**. This is the realms of enterprise governance. Governance actions are distinct from executive, managerial, and operational actions, because they are geared towards the preservation of the enterprise self-awareness. Hence, governance focuses on the design rules and principles that constrain the enterprise actors, along with their actions and interactions.

**Principle 5 Maintaining the enterprise as a single entity requires actors to dynamically maintain a view of the actual state of the enterprise**.

The previous principles state the relationships between an individual actor and its own dynamic control system. But how do the multiple actors, either carbon or silicon, interact and produce composite behaviour? Using a metaphor: what makes a group of heterogeneous and autonomous musicians become a musical ensemble? Why is this collective entity more than the linear sum of its individual parts? So, what defines the boundary of an enterprise? What forces bind together its autonomous actors as a single entity? We believe that the answer to this question lies in the enterprise's "semantic model of itself". We call this *enterprise self-awareness* (Abraham et al. 2013; Potgieter and Bishop 2003; Santos et al. 2008). This means that if an enterprise has a common semantic model of its actors then in becomes a single collective entity. If there is no common semantic model then the actors are unable to be self-aware of their context and as a result no single collective entity can be defined. This semantic model is a shared dynamic model that is constantly updated by all its active components. It is precisely this shared semantic model that defines a musical ensemble: each musician has its own role, but both individually and as a whole they are self-aware that they share the goal of playing the same piece of music according to a set of rules.

The systemic nature of an enterprise and its cybernetic attributes stress the need for having engineering artefacts to support the collective understanding of its changing reality. Enterprise cartography is fundamental to support this task. Furthermore, this enterprise engineered augmented capability is essential to support the increasing challenges of enterprise governance, which are essential to preserve the integrity of an enterprise as a collective entity. The next section describes the goals of principles of enterprise cartography.

## 4 Enterprise Cartography

Cartography is the practice of designing and creating maps. It is based on the premise that reality can be modelled in ways that communicate information effectively. Enterprise cartography deals with providing up-to-date model-based views of an enterprise architecture and its goal is facilitating its communication and analysis. We have been successfully applying enterprise cartography concepts to enterprise architecture projects (Caetano and Tribolet 2006; Caetano et al. 2009, 2012b; Sousa et al. 2007, 2009) and developing computer-based tools to support enterprise cartography (Caetano et al. 2012b; Filipe et al. 2011; Sousa et al. 2011). Currently, the principles described here are implemented in a commercial tool that is being used in several medium and large scale enterprise architecture projects[1]. This section describes some empirical findings that we have observed in these cases.

The concept of abstracting reality through representations is not limited to engineering disciplines. Cartography itself is an established discipline that has played a major role in the development of mankind. Cartography is an abstraction process that systematically and consistently transforms an observation of reality into a map or a graphical representation. The production of a map embraces many different concerns, including scientific, technical, and purely aesthetic. Enterprise cartography denotes the discipline that deals with the conception, production, dissemination and study of the maps of an enterprise to support its analysis and collective understanding.

Classic cartography is usually associated with the representation of static objects, as in the case of geographic maps. Modern cartography deals with the representation of both static and dynamic objects and is commonly grounded in information science, geographic information science and geographic information systems. Cartography must also provide multiple consistent views of the same system. For example, geographical maps often combine different views, such as political boundaries, topographic features and several other features. This entails defining

[1] http://www.link.pt/eams/

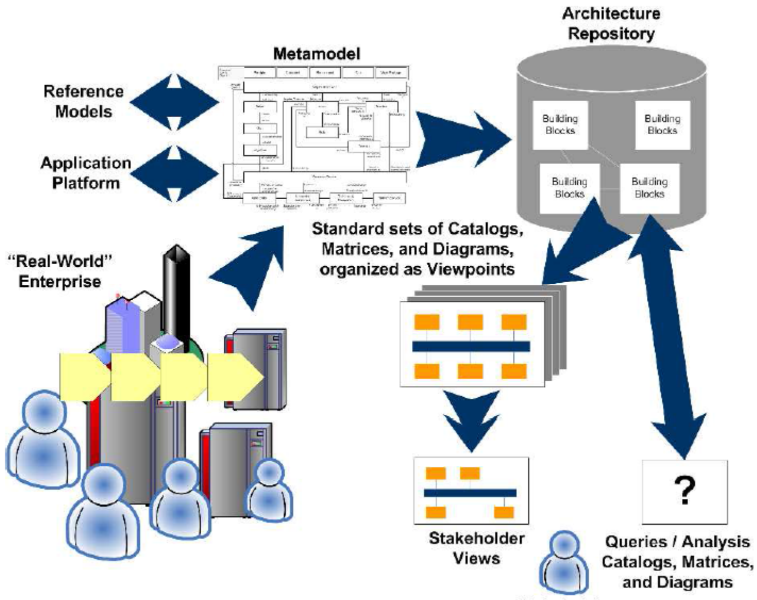


*Figure 3: Relationships between meta-model, views, viewpoints, diagrams, and stakeholders, adapted from (The Open Group 2009).*

abstraction rules and classification mechanisms so that all of views are consistent. The cartography of dynamic objects also requires to abstract the rules that constrain how objects change and relate to each other over time.

Enterprise cartography deals with the dynamic design and production of architectural views that depict the components of an organisation and their dependencies. It shares its constructs with enterprise architecture, such as meta-models, models, views, repositories, frameworks, and design rules. However, its goal is descriptive. A *view* expresses the architecture of a system from the perspective of concerns defined by its stakeholders. Views are defined by *viewpoints*, which establish the conventions for the construction, interpretation and use of architecture views (ISO/IEC/IEEE 2011; The Open Group 2009). Figure 3), taken from the TOGAF 9 specification, illustrates the basic relationships between these concepts. The following principles distinguish cartography from enterprise architecture.

**Principle 1 Enterprise cartography uses observations to produce the representations of an organisation**. The process of organisational data collection is a core concern of enterprise cartography. Data collection is not a concern of the mainstream approaches to enterprise architecture.

**Principle 2 Enterprise cartography focus on the dynamic description of an organisation**. It does not deal with the processes or governance of organisational transformation. The purposeful transformation of organisations is addressed by enterprise architecture.

**Principle 3 Enterprise cartography keeps up-to-date architectural views**. This implies automated or supervised data collection and view creation. Ideally, these tasks should be performed at the same frequency as that of organisational change. Enterprise architecture techniques do not aim to provide systematic support for data collection nor the automated design and creation of views, meaning these tasks are usually manual and creative.

### 4.1 Approaches to Enterprise Cartography

There are several approaches to generate organisational models from the data extracted from enterprise systems. Configuration Management Databases (CMDB), as defined by ITIL (Adams 2009), manage the configurations and relationships of information systems and technological infrastructure. To populate a CMDB, some solutions provide auto-discovery techniques that detect nodes, virtual machines and network devices to create infrastructural views. Auto-discovery is actually a cartographic process and requires that the type of the concepts to be discovered is specified in advance (Filipe et al. 2011). The resulting CMDB instance will contain a partial model of the organisation's infra-structure. This model can be communicated through different but consistent visualisation mechanisms, such as textual reports or graphical models that are designed according to a symbolic notation and design rules (Lankhorst 2013).

At the business and organisational layer there are several cartographic techniques defined by business process management (Dumas et al. 2013) and process mining (Aalst et al. 2012). These techniques make use of event logs to discover process activities, control and data flows, as well as organisational structures (Aalst 2011; Aalst et al. 2012; Agrawal et al. 1998). In this case, discovered processes correspond to actual instances of processes, not to the designed processes. Model analysis can also be used to assess the conformance of processes against constraints (Caetano et al. 2012a; Molka et al. 2014). Another example of enterprise cartography is the inference of inter-organisational processes based on EDI event logs (Engel et al. 2012). Semantic technologies, such as ontologies, can also be used to analyse enterprise models (Antunes et al. 2013, 2014). Business intelligence techniques that collect data from organisation systems to produce reports and dashboards are another example of cartography (Negash 2004). Business intelligence actually supports the feed-back control loop by providing managers with a model of the organisation that allows them to ground their actions and decisions.

Enterprise cartography is already a reality in several domains. However, handling dynamic objects, time and change is not explicitly addressed by most approaches. We aim at a generic and systemic approach, very much in line with the concept of ”Enterprise Architecture Dashboard” (Op't Land 2009), that displays the enterprise current and future states, its performance and the directions of the organisation transformation process.

### 4.2 Principles of Enterprise Cartography

This section describes a set of principles that define Enterprise Cartography. These principles use the following definitions.

**Project** is an transformation process designed to achieve a goal specified by a *to-be state*.

**Organisation variable** references specific information or a value associated to an organisational artefact.

**Organisation state** contains the values of a subset of *organisation variables* at a given point in time.

***As-was* state** is the set of all *organisation states* observed in a specific point in the past.

***As-is* state** is the set of *organisation states* as observed in the current point in time.

***To-be* state** is the set of *organisation states* that are predicted to occur in a specific point in the future.

**Principle 4 The *as-is* state is defined by the *as-was* and *to-be* states.**
Memory of the past state (*as-was*) and the future state (*to-be*) define the behaviour of an organisation. The *to-be* state specifies the goals of transformation projects. Without the *to-be* state the transformation processes cannot be executed or measured since no project goals are defined.

**Principle 5 The definition of the *to-be* state always precedes the definition of the *as-is* state.**
Organisational artefacts must be always defined as goals in the *to-be* state before being captured in the *as-is* state. This means that the organisational artefacts are not created incidentally but always as the result of a transformation project.

**Principle 6 All organisational artefacts can be classified as being in one of four invariant states.**
**Gestating** is the state that describes an organisation artefact after it is *conceived*, i.e. after it starts being planned, designed or produced. At this state, the artefact does not yet exist as an active element of the organisation in the sense it is not yet able to produce behaviour but can be passively used by organisational transactions and processes.
**Alive** is the state that an artefact enters after *birth*. Birth is the event that signals the moment when a *gestating* artefact enters the *alive* state. This means that the artefact is now able to produce behaviour as part of the organisational transactions and processes.
**Dead** is when a *gestating* or *alive* artefact is inactive in the sense it is no longer able to play a role in the organisational transactions and processes. This state is the opposite of *gestation* that brought the artefact into existence. However, a *dead* artefact may still have impact on the organisation. For example, an application or server enter the *dead* state when they stop operating and will remain in that state until they are fully retired from the organisational infrastructure.
**Retired** represents the post-death state where the artefact is unable to further interact with other artefacts.
Organisational artefacts exist first in the *to-be* state and only then in the *as-is* state. This applies to each state transition of the artefact's life-cycle. Artefacts are conceived as the future result of a project, thereby entering the *gestating* state. They remain in this state until the project successfully completes. After that the artefact becomes *alive*. An *alive* artefact *dies* when a decommissioning project completes. A *gestating* artefact can also die if the project is cancelled or not completed. A *dead* artefact is *retired* when a retirement project explicitly removes the artefact from the organisational structure. Therefore, all state changes applying to an artefact are the result of a transformation project. As such, the *to-be* state always precedes the *as-is* state (Sousa et al. 2009).

**Principle 7 Organisation models and projects plans are fundamental artefacts.**
Organisation models and project plans must be observed as variables whose values are captured during the *as-is* state assessment. This also means that architectural views, viewpoints, models and other architectural artefacts should be regarded as organisation variables. For example, the repository of a UML modelling tool holding the specification of a system under development must be an organisation artefact because it contributes to the specification of the *to-be* state. In contrast, a project is often regarded as an organisation artefact. For instance, both TOGAF and ArchiMate explicitly consider the concept of project Work Package. However, organisational models, viewpoints and views are not explicitly regarded as artefacts by enterprise architecture modelling languages. Nonetheless, system architecture guidelines such as ISO 42010 point out the importance of considering these elements as system artefacts (ISO/IEC/IEEE 2011).

**Principle 8 The *to-be* state is sufficient to plan a transformation project.**
For the purpose of planning a transformation project the current *as-is* state is not required because the *to-be* state must fully specify the organisational goals.

### 4.3 Discussion

Figure 4 depicts a time line and a series of events in time (T0-T5). T0 represents the current moment, therefore indicating the instant the *as-is*

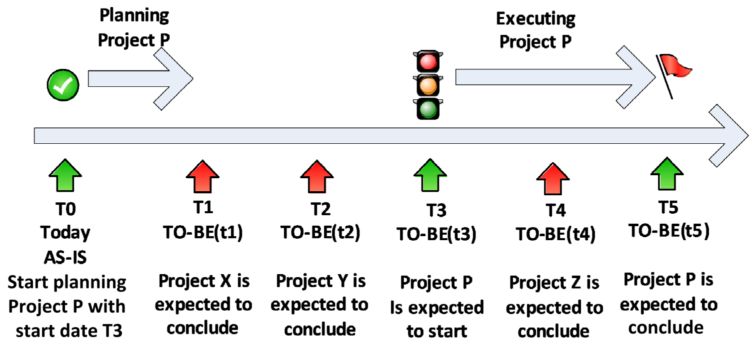


*Figure 4: Project planning and execution.*

state was captured. At T0 the project P is conceived and enters the gestating state: this project is planned to start at T3 and to be completed at T5. Events T1, T2, T4 signal the completion of projects X, Y and Z, respectively. Therefore, T1, T2, T4 also indicate that the artefacts that were produced by these three projects became *alive*. Since project P is planned to start at T3 the organisation requires knowing about its state at state *to-be*(T3) and not at state *as-is*(T0) although planning is actually taking place at T0. This happens because the completion of projects X and Y at T1 and T2 may interfere with the execution of P at T3. Furthermore, the organisation also requires knowledge about its state at T4 because the changes resulting from project Z may also interfere with project P.

To plan a transformation initiative an organisation needs to be aware of the set of *to-be* states while the project is being executed. A description of the *as-is* state for planning purposes is actually of limited use because there is often a temporal gap between project planning and project execution. On the other hand, other projects conclude and change the organisation state while the project stands between planning and executing. These observations minimise the relevance of the *as-is* state as a means to design the transformation processes of the organisation.

As an example, consider an organisation that plans the replacement of a system in 6 months time and starts today the corresponding project plan. The project planning phase must have an understanding of the dependencies between that system and other systems, as well as to the business processes it supports. If no state changes occur in the next 6 months, then the organisation can indeed rely on the *as-is* state to plan the replacement project. But if the organisation is performing a set of additional transformation projects that will change the organisation's state during that period, then planning the system replacement project will require knowing about the sequence of *to-be* states during the next 6 months and during the actual execution of the replacement project. Otherwise, it will not be possible to plan according to the actual network of dependencies between the system to replaced and other organisational artefacts. Therefore, for the purpose of project planning and execution, the current *as-is* state will often not mirror the organisation's reality. In fact, the relevance of the *as-is* state is inversely proportional to the number of projects being completed per unit of time. At the limit, all dependencies of the system to be replaced may change between the planning and execution phases, meaning that all *as-is* state variables will become irrelevant for planning purposes.

Nevertheless, the knowledge about an organisation's current state is a fundamental asset for its operational management. At operational level, actions and reactions are based on near real-time observations and events, meaning that planning and execution occur in close sequence. However, the requirements of the near real-time operational level of an organisation should not be intertwined with the medium to long-range requirements required for organisational transformation and governance.

## 5 Conclusions

Organisations do plan and execute projects, regardless of not having a full or accurate representation of the *as-is* or *to-be* states. Such an accomplishment implies that projects include to some degree an assessment of the impact of change between and during planning and execution.

An organisation that does not have a representation of its *to-be* state will be unable to create a detailed plan of project P as depicted in Fig. 4. This means that parts of the plan must be postponed until T3 to minimise the gap between the planning and execution of P. This reality is commonly observed in many organisations despite having impact on the project costs and risk, and staff assignment. It also interferes with the planning of other projects, thereby having negative impact on the organisation's agility. To remedy this issue, enterprise architecture projects often attempt to obtain a complete and accurate representation of the *as-is* state. As a result, the primary goal of these projects is an attempt to keep an organisational repository updated with an observation of the *as-is* state. This approach is often justified by statements such as "knowing in detail where we stand today is a pre-requirement to any transformation project." Although this sounds wise, this is a demanding task in terms of effort and time. Moreover, and as discussed before, the rate of organisational change will make the *as-is* state obsolete for the purpose of transformation planning. Therefore, we posit that organisations should reassess the actual value of enterprise architecture projects that aim capturing the *as-is* state as an enabler of transformation planning.

This dilemma is found in many organisations: the contrast between the notion that an *as-is* assessment is a valuable asset for organisational transformation, and knowing at the same time that achieving such continuous task is demanding. This paper defends that an organisation does not need to have a full and accurate depiction of the *as-is* state but of its *to-be* state. The *to-be* state is specified according to the specific goals of projects, that are required for planning purposes. This contrasts with the *as-is* state that requires observing the variables of all organisational artefacts that are not retired. Consider a project that aims creating a new system that will interact with an existing legacy system. Planning this project requires collecting information about the legacy system as well about the design of the new system. However, the task of collecting information about a legacy system for the purpose of project planning is actually contributing to extending the knowledge about the current state of the organisation. This is a potential avenue to sort out the dilemma stated earlier because a representation of the *as-is* state can be built incrementally by specifying the *to-be* state(s) that are required to plan the multiple projects of an organisation.

This position paper has presented a general framework that provides representations of dynamic organisations in the context of enterprise engineering. It specifically describes a set of principles grounded on dynamic systems theory that provide guidelines on how to represent a cartographic representation of an organisation. Such representations facilitate the planning of organisational transformation.

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Jorge L. Sanz

# Enabling Front-Office Transformation and Customer Experience through Business Process Engineering

*The scope of business processes has been traditionally circumscribed to the industrialisation of enterprise operations. Indeed, Business Process Management (BPM) has focused on relatively mature operations, with the goal of improving performance through automation.*
*However, in today's world of customer-centricity and individualised services, the richest source of economic value-creation comes from enterprise-customer contacts beyond transactions. The need to make sense of a mass of such touch-points makes process a prevalent and emerging concept in the Front- Office of enterprises, including organisational competences such as marketing operations, customer-relationship management, campaign creation and monitoring, brand management, sales and advisory services, multi-channel management, service innovation and management life-cycle, among others.*
*While BPM will continue to make important contributions to the factory of enterprises, the engineering of customer-centric business processes defines a new field of multi-disciplinary work focused on serving customers and improving their experiences. This new domain has been dubbed Business Process Engineering (BPE) in the concert of IEEE Business Informatics.*
*This paper addresses the main characteristics of BPE in comparison with traditional BPM, highlights the importance of process in customer experience as a key goal in Front-Office transformation and suggests a number of new research directions. In particular, the domains of process and information remain today disconnected. Business Informatics is about the study of the information process in organisations and thus, reuniting business process and information in enterprises is a central task in a Business Informatics approach to engineering processes. Among other activities, BPE is chartered to close this gap and to create a suitable business architecture for Front-Office where organisational and customer behaviour should guide and benefit from emerging data analytics techniques.*

## 1 Process is out of the Industrialisation Box

Business process has been at the center of the stage in both research and industry for several decades. Under the brand of Business Process Management (BPM), business process has attracted a great deal of attention from many practitioners and scholars. BPM has been defined as the analysis, design, implementation, optimisation and monitoring of business processes (Dumas et al. 2013; Franz and Kirchmer 2012; Rosenberg et al. 2011; Schönthaler et al. 2012; Sidorova and Isik 2010). Aalst et al. (2003) defined some targets of BPM: "*. . . supports business processes using methods, techniques, and software to design, enact, control and analyse operational processes involving humans, organisations, applications, documents and other sources of information.*"[1]

While the above definitions are quite comprehensive and broad, in reality most BPM research and industry activity has grown upon the motivation of reducing operating costs through automation, optimisation and outsourcing. There are a several Schools of thought and practice (such as lean, lean sixsigma, and others (Andjelkovic-

[1] Aalst et al. (2003) exclude *strategy processes* from BPM, a remarkable pointthat will be revisited in more depth later in this paper.

Pesic 2007; Andjelković Pešić 2004, 2006; Näslund 2008)) and a myriad of related literature in the last 40 years that serve to illustrate the focus on cost contention. Around the middle of the past decade, T. H. Davenport (2005) stated in a celebrated Harvard Business Review paper that processes were being "*analyzed, standardized, and quality checked*", and that this phenomenon was happening for all sort of activities, stated in Davenport's own terms: "*from making a mouse trap to hiring a CEO*". The actual situation is that industry investment and consequential research have stayed much more on "trapping the mouse" than in differentiating customer services through innovative and more intelligent processes, let alone hiring CEOs. This may be explained partly from Davenport's own statements in 2005: "*Process standards could revolutionize how businesses work. They could dramatically increase the level and breadth of* ***outsourcing*** *and* ***reduce the number of processes that organizations decide to perform for themselves***" (bold face is added here for emphasis).

With the advent of different technologies such as mobile, cloud, social media, and other digital capabilities that have empowered consumers, the classical approach and scope of business process have begun to change quickly. Organisations are adopting new operating models (Hastings and Saperstein 2007) that will drastically affect the way processes are conceived and deployed. As stated by many authors in the last four decades, business process work is supposed to cover all competences in an organisation, irrespective of the specific skills from human beings participating in such operations. However, in an unpublished inspection of about 1,300 papers conducted by the author and some of his collaborators[2], most process examples shown in the literature deal with rather simple forms of coordination of work, mostly exhibiting a flow structure and addressing administrative tasks (like those captured in early works on *office information systems*).

[2]The co-authors are L. Flores and V. Becker both from IBM Corporation.

Furthermore, the examples provided usually deal with rather idealised operations, probably offered as simple examples with the purpose of illustrating theoretical or foundational research results (Aalst 2004; Aalst and Hee 2002; Aalst et al. 2003; Yan et al. 2012). Thus, radically simplified versions of "managing an order", "approving a form", "processing a claim", "paying a provider", "delivering an order" etc. are among the most popular examples of processes found in the literature.

The lack of public documentation of substantial collections of real-world processes is remarkable. Houy et al. (2010) both confirmed the dominant focus on simple business processes and also suggested potential practical consequences of related research: "*. . . there is a growing and very active research community looking at process modelling and analysis, reference models, workflow flexibility, process mining and process-centric service-oriented architecture (SOA). However, it is clear that existing approaches have problems dealing with the enormous challenges real-life BPM projects are facing [. . . ] Conventional BPM research seems to focus on situations with just a few isolated processes . . .* ". Of course, the list of available real-world processes would be a lot richer if one included the set defined by enterprise packaged applications (Rosenberg et al. 2011). However, this comprehensive collection is proprietary because it constitutes a key piece of intellectual capital coming from software vendors or integrators in the industry.

The traditional focus on process has also raised much controversy. At the S-BPM ONE Conference in 2010, a keynote speaker (Olbrich 2011) remarked: "*Let me be as undiplomatic as I possibly can be without being offensive [. . . ] The academic community is as much to blame [. . . ] as the vendors of BPM systems, who* ***continue to reduce the task of managing business processes to a purely technological and automation-oriented level***". While other authors in the same conference debated "who is to blame" very animatedly (Fleischmann 2011; Singer and Zinser

2011) it is important to highlight that the statement from Olbrich (in bold face above for emphasis) reinforces that BPM has mostly followed the obsession of automation and optimisation by means of Information Technology.

A detailed inspection of the extant literature confirms that business process work has been devoted to a rather small fraction of the actual variety and complexity found in enterprise behaviour. This behaviour enacts many valuegenerating capabilities that organisations cultivate based on skills provided by their own workforces and through rich interactions with other enterprise stakeholders, particularly customers. The following points offer a simplified summary:

(1) Business process research in Computer Science has been traditionally focused on certain classes of enterprise operations, mostly involving simple coordination mechanisms across *tasks*. This type of coordination and the overall behaviour represented in underlying models reflect very much an "assembly line" where work is linearly synchronised to deliver a desired artifact or outcome. BPMN, emerged from OMG as the industry standard for business process modelling is a good illustration of this point. Simplicity of the choreography is ensured by removing any form of overhead in communication when moving from one stage to the next. Unlike other more complex business processes, many software applications do have this simplified structure. In fact, a trend since the early 2000's is to separate the specific application logic from the coordination / choreography needed across modules, and both of them from the actual data contained in a data-base management system. Different foundations and a plethora of languages have been created to capture this semantics of coordination such as Business Process Modelling Notation (BPMN), Business Process Execution Language (BPEL), Unified Modelling Language (UML), Event Process Chain (EPC), Petri Nets, etc.

(2) Resulting process models have typically yielded the form of a "workflow" (Sharp and McDermott 2009; White 2004). This means that the activation of a task in the assembly line only occurs when certain predefined events take place, one or more previous tasks are completed and their produced artifacts transferred to the next task in the pipeline for continuing "the assembly". In fully automated systems, like software applications, this is a good abstraction (see Fig. 1). On the other hand, in actual business processes where humans participate or supervise the individual tasks, workflows do not always capture the actual pattern of work, including the contractual commitments made across role-players.

Consequently, IT systems used to implement such workflows, called "Business Process Management Systems" (BPMS) in IT jargon[3], are not suitable to communicate the nature of work to business stakeholders. This point has been extensively addressed in recent Enterprise Engineering work (Dietz et al. 2013), such as DEMO and related contributions (Albani and Dietz 2011; Aveiro et al. 2011; Barjis et al. 2009; Proper et al. 2013). The issue of clarity was brought up by Dietz eloquently during a key-note entitled "Processes are more than Workflows" in the 2011 KEOD Conference: "*With modelling techniques like Flowchart, BPMN, Petri Net, ARIS/EPC, UML and IDEF you get easily hundreds of pages of process diagrams. Nobody is able to understand such models fully. Consequently, nobody is able to redesign and re-engineer a process on that basis*".

Beyond communication issues, the distinction of contexts between an organisational design

[3]The term BPMS is somewhat questionable because it implies that these IT systems implement processes while they actually do so only for very special types of processes, i.e., workflows. Thus, the earliest denomination of Workflow Management Systems (WMS) is more adequate. As an example, *Cases* emerged later in the software industry and model more complex processes. The term Case Management Systems (CMS) has been used to distinguish them from BPMS. This incorrectly implies "cases are not business processes".

concern and an IT concern should also be carefully addressed. In the workflow abstraction, the potential role-players assigned to the execution or supervision of the individual tasks will be "idling" unless they get activated through the pipeline. This model of reality is well-suited to fully automated tasks (like those realised by software) but unsuited to other situations in organisations where humans take part of the process execution.

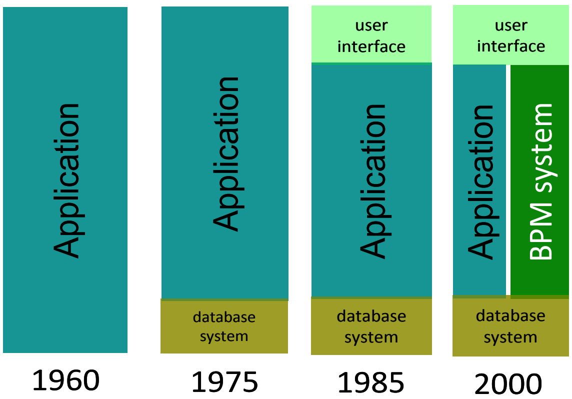


*Figure 1: The evolution of information systems development and the role of BPM systems in the newest generations of software (from Aalst et al. 2003).*

Indeed, the factory model of operations captured into a workflow implies that people are actually "doing nothing" unless their "activation" occurs by the preceding tasks in the pipeline. The latter is far from modelling accurately the reality of work in most enterprise processes.

(3) The tradition of business process management works on the assumption that the investment made in optimally designing a process will be recovered through the repeated application of the process for a long-enough period of time. The principle is that economic benefits will accrue from accumulated cost reduction obtained by the application of the optimised process over and over again. This approach reflects a true *'factory'* in the conception and modelling of organisational behaviour. Furthermore, the idea of perfecting the process with such an effort paying off through hundreds of thousand repetitions or even millions of interventions done with the same process is adversarial to the business need of introducing modifications. As organisations have been progressively more affected by sudden change or involved in operations where change is a common requirement this type of *factory optimisation* does not work. In fact, rigidity of process models has been a long-standing and bitter finding. More recently, the broader issue of process evolvability in the presence of continuous change has been the subject of solid research, including a recent PhD thesis (Nuffel 2011) and references therein.

(4) Implicitly or explicitly in the traditional approaches to business process, it lies the Taylorian principle of replacing individuals by applying automation whenever possible. As in other business theories that build on a "dehumanisation" of enterprises, the consequence is that the role of humans as sources of value-creation in processes is ignored. The connection of this foundation and BPM work has been openly recognised by Van der Aalst in his recent review of a decade of Business Process Management conferences Aalst (2012): "*Adam Smith showed the advantages of the division of labor. Frederick Taylor introduced the initial principles of scientific management. Henry Ford introduced the production line for the mass production of black T-Fords. It is* ***easy to see that these ideas are used in today's BPM*** *systems*".

In close connection to this moral coming from certain economics and business schools, it also resides the goal of avoiding *variation* of the process by all possible means. This good idea originally coming from manufacturing practices (i.e., reducing variation as a means to controlling quality and cost of the resulting production) has been translated to other forms of operations (such as *services*) where variation is inevitable when interaction with non-automated agents becomes an integral part of the actual production process.[4]

[4]Most call centers begin all their interaction with customers by following pre-established routines. In some cases, this may disgrace the effectiveness of the service and satisfaction of the caller. A known example is when reasonably

Inevitable process variation is a significant sign of 'lost control', as organisational capabilities go from the tangible to the less tangible. As said in Le Clair (2012), *the less tangible the capability, the more control will be ceded to the customer.* The tradition of BPM work contrasts sharply with Enterprise Engineering (Dietz et al. 2013), a theory in which humans are seen as a precious source of value, particularly for achieving improvements and differentiation. In particular, all processes involving interaction with customers offer this opportunity (services researchers often call this concept "co-creation").

(5) It is important to recall that existing *process classifications* such as the Process Classification Framework (Process Classification Framework (PCF)) reveal common areas of work in organisations that do not follow the BPM tradition in the sense that they do not represent work amenable to workflows. Indeed, PCF is a standardisation effort in different industries that includes many non-factory areas of an enterprise. Consequently, these operations are not adequately addressed by the application of existing BPM research, methods and tools.

The clarification from Van der Aalst and his collaborators when excluding *strategy processes* from the scope of their work was an excellent and very early sign, although "strategy" should not have been the only area excluded from the scope of their contributions. Indeed, there are other critical business processes in enterprises beyond "strategy" that do not fit workflow models, Petri Nets, BPMN, or related instruments popular in Computer Science (Sanz et al. 2012). Specifically, these other forms of organisational behaviour beyond '*the factory*' involve complex activities carried our by humans in collaboration with one another and with the support of technology in ways that are observable and may also be captured into process models. This point can also be easily illustrated by using some of the Process Classification Framework (PCF) content.

While some people may argue that this framework may arguably be called a process architecture (Eid-Sabbagh et al. 2012; Miers 2009; M. A. Ould 1997) it still provides a solid clue of many operations that are either common across industries or unique to specific industry segments such as retail banking or consumer packaged goods. None of these enterprise operations can be modeled by workflows.

In addition, the componentised business architecture and its resulting industry models addressed in Sanz et al. (2012) are also very useful to illustrate the same points. In these approaches, there is no functional decomposition at the heart of the modelling, unlike in PCF, and thus the resulting construction follows more closely some of the core principles of Enterprise Engineering (Dietz et al. 2013). This will be addressed briefly in the next section.

(6) Another important evidence that process has moved out of the industrialisation box is *Case Management* (more recently also called Adaptive *Case Management* by the authors in (Swenson et al. 2010) and *Dynamic Case Management* by analysts in Forrester). The need for Case Management has been illustrated with different enterprise operations such as claim processing in Property and Casualty Insurance, customer applications in Social Services, Health Care claim processing, Judicial Cases, and so on. Van der Aalst and others (Aalst and Berens 2001; Aalst et al. 2005) presented *Case Handling* as a new paradigm for supporting *flexible* and *knowledge intensive* business processes. In his work on case management, De Man (2009) states that 'workflow' is an adequate representation for factory-type, highly predictable behaviour admitting for little or no deviation from pre-established models. In recent literature (Khoyi 2010), the argument in support of the need for Case Management hinged around the fact that "*Case Management allows the business to be described in known terms rather than artificially fitting it into a process diagram*".

educated customers are asked first whether their obviously nonfunctioning product is plugged to the power supply, to unplug and plug it again, try to turn it on once more, and so on.

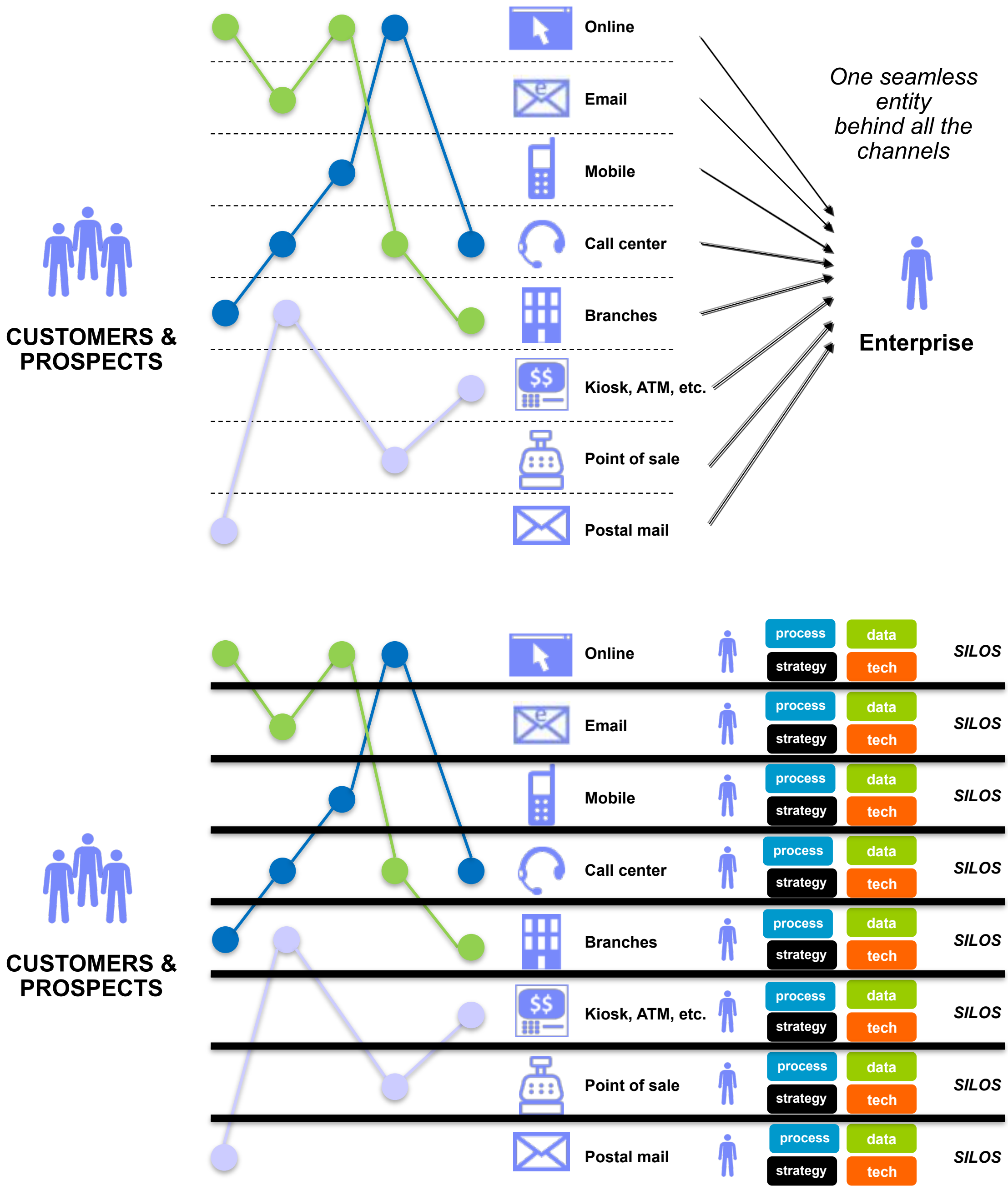


*Figure 2: Customers and prospects deal with an enterprise through a number of channels by following patterns or Journeys that vary according to individuals' goals and behaviour. The picture on the upper side represents the expected experience of meeting the enterprise as a single and well-integrated entity. However, reality is very different as channels are not well-integrated, represented visually by the horizontal silos of the lower side picture. Each silo has their own processes, data, strategy (incentives) and IT. Thus, a Customer Journey is the integration of individual customer-enterprise touch-points to realise a specific customer outcome. These Journeys are essential processes deeply related to loyalty and other significant measures of customer experience, unlike traditional customer satisfaction metrics.*

## 2 Process and the Broken Customer Experience

In the context of this paper, customer experience is the conjunction of all experiences a consumer has with an enterprise over the duration of their relationship (Harrison-Broninski 2005). Customer experience is critical for enterprises because it has been widely understood as a key factor driving customer loyalty (Propp 1968). Poor customer experience in business-toconsumer enterprises has been a top concern in organisations for longer than five years. The main reason is the profound lack of loyalty that customers exhibit in the business-toconsumer (b-to-c) industries (Capgemini 2012).[5] While this challenge has been commonplace in many industry segments, the problem is particularly acute in most b-to-c services organisations where many initiatives have been taken to address the problem, even to the point of introducing a new role at the top management level called *Customer Experience Officer* (Bliss 2006).

The advent of multiple channels of engagement for the same enterprise exposes deeper gaps in the way organisations deal with their customers. Indeed, multiple channels have generated even more disconnects with customers as these channels are generally managed by different organisational units and have isolated measures of performance. Traditional customer satisfaction measures tend to focus on individual customer interactions on a specific channel but these do not seem to correlate positively with customer loyalty (Rawson et al. 2013; Stone and Devine 2013). Figure 2 illustrates customer interactions[6] taking place across different enterprise channels (upper side of the Fig.). These patterns are typical for a single customer pursuing a specific outcome. In most organisations, each channel behaves as a silo (lower side of the Fig.) thus having its own strategy, goals, processes, data and technology. This disconnect across channels impacts customer experience quite negatively. In summary, **a much more engaged consumer through multiple channels is making the already disrupted customer experience *unmanageable* for large enterprises**.

All these challenges lead organisations to revisit some of their core competences related to customer experience. In fact, a number of key capabilities have been emerging over the last decade, starting to yield best-practices for front-office operations (Hastings and Saperstein 2007). However, it is the **lack of understanding, modelling and instrumenting critical customer journeys the main reason why customer experience continues to be disrupted and has got worse with the advent of more channels**. Furthermore, aligning these *customer journeys* with back-office operations yielding end-to-end business processes is essential to enable customer experience. Business analysts characterised this new process trend directly affecting customer experience under different names and also alerted practitioners, researchers and process professionals about different shifts taking place along the entire "hype cycle" of process evolution. In particular, Forrester used the name "tamed processes" and characterised them as follows: "*Tamed processes are designed from the outside in, can be driven by big data and advanced analytics, support social and mobile technology, provide end-to-end support*

[5] In North America, 80% of clients are "happy" with their bank service but **only 50% say they will remain with their current bank over the next 6 months**. This reflects the finding that globally, only **42% of bank customers have rate their experience as being positive**. Furthermore, satisfaction levels with branches, despite being the most expensive and most developed channel, averages 40% worldwide with highest being 60% in North America (Capgemini 2012).

[6] The set of customer-enterprise interactions followed to achieve a specific outcome for an individual costumer has been named *customer journey* (Rawson et al. 2013). This term has probably been coined by some technical and business people with the goal of implying that the concept should not be made part of the classical "process grinding" experienced though four decades of BPM, lean six-sigma and the like. Beyond communication intent, *journeys* are processes and this is a well-supported fact in Social Science work.

*across systems of record and functional areas, and link on-premises and cloudbased services*" (Le Clair 2012).

**Engineering (i.e., designing and running) these *customer journeys* is a very different problem from those BPM has been focusing in four decades**. These needs around modelling and architecting for customer experience are in sharp contrast to applying Customer Relationship Management (CRM) packaged applications used to monitor sales, manage customer center calls or design optimised workflows for efficient backoffice processes. In fact, there is a risk that software may be used precipitately for supporting enterprise capabilities related to customer experience. Indeed, some of these emerging practices are being made into software without adequate exposure of the underlying business processes. This should constitute a warning to management as **these software applications bury rich business processes into their packaged software**, thus signaling the same issues experienced in mature back-office operations. This warning is a significant call for the adequate research and practice necessary to **surface the key processes before they are fully embedded into "concrete"**, a fact that will impact agility as the frequency of change in these processes is a lot higher than in those modeled in conventional enterprise resource planning. Traditional approaches to business process instrumentation based on packaged applications in conjunction with custom BPM systems come to memory after four decades of cost-take out and efficiency improvements. In part, this rigidity has created *fragmented* customer experience as a consequence of the lack of flexibility and long time-to-value for desired changes in the information technology systems deployed across the enterprise. This is an observation coming from direct practice in the field and can also be corroborated by exploring a very extensive business literature. In short, **if front-office processes are not addressed according to the new business and societal needs, the ongoing fragmented experience will result in additional loss of loyalty and consequently, customer equity or profitability issues** (Villanueva and Hanssens 2007).

Probably to the surprise of many data analytics advocates, if customer-centric processes are not engineered to reflect the demands from the new economy, the emphasis on *individualising customers* and "inferring their behaviour" will just make customer experience even worse. The reason is that customers will increase their expectations for personalised services while the ability for organisations to address this expectation remains far from the current state-of-the-art. This issue will become particularly challenging for some services industries because (i) such personalisation may not be viable due to the nature of the service being delivered; (ii) personalisation requires in many cases a co-created design and delivery, a pursuit that many enterprises are not yet in a position to address; (iii) regulatory limitations may prevail thus limiting the enterprise to discriminate across customers; or (iv) scalability of good quality customer service may be at odds with profitability targets. This remark is an attempt to warn "data scientist" approaches to front-office operations, as the main disconnects will only be widened by "data-only" insights.

## 3 Process in critical areas of the Front-Office

The term "Front-Office" is used here to denote the set of enterprise activities and resources dedicated to the support of customer experience. In this category, they fall many customer service management operations. But other Front-Office areas in organisations also go beyond the purpose of dealing directly with customers. Some examples are brand monitoring, campaign design and deployment, enterprise marketing operations, product and service innovation, customer loyalty and advocacy management and others among the top areas where organisations have been investing in the last decade or so. These enterprise capabilities and related competences support customers indirectly, although boundaries may blur in some cases (for example, a campaign design may involve realtime intervention based on customer interactions). These capabilities are beginning to have more visible best-practices and thus, corresponding business processes are emerging. Consequently, their study is at the realm of Business Process Engineering because they encompass key work-practices. These operations involve humans and collaborative activities deeply interrelated with technology and information, and their patterns of work are also emerging, become more and more visible, being subjected to *white box modelling* rather than remaining as *black boxes*. In these new process areas, Information Technology will still be essential but in radically different ways from "the factory" of enterprises. Actually, translating those experiences from Information Systems in the Back-Office to the Front-Office is a sure recipe for disaster. This inadequate translation would also add significant longterm strategic and cost-centric consequences to the ongoing broken customer experience.

Searching for further practical evidence on the emergence of non-traditional enterprise areas needing process study, it is important to revisit in depth some theories of organisational design and related work by different business research schools (Penrose 2009). Figure 3 shows an organisation of the resource-base of a typical enterprise into four distinct types and the corresponding bundling of such resources into disjoint business components. Each column on the right hand side of the Fig. represents one typical competence whose organisation is described by the generic concepts of the column on the left, as presented in Sanz et al. (2012). Although a different language was used, the foundations of the structure of a generic competence should be honored to Brumagin in Brumagim (1994), among other more recent business researchers.[7]

Notice that the hierarchy of resources represented in Fig. 3 does not mean the same as the classical management concept of "control". Instead, it only represents an arrangement in which different skills, information, assets (intangible and capital) and derivative entangled capabilities are bundled together to produce one or more relevant outcomes in the enterprise. Likewise, these components are not necessarily aligned with traditional Lines-of-Business and do not intend to map departmental capabilities or other conventional "reporting structures" in enterprises. Revisiting Penrose (2009), the components highlighted on the right may be thought as the formalised grouping of resources whose entanglement produces those core services (internal or external) that the organisation needs to serve all stakeholders. Some enterprises may be endowed with some of these resources in unique ways, being also more idiosyncratic for some industries than others.

Concrete models recently built for many industry segments by following the modularisation principles reveal that there are hundreds of business components that the business process tradition has failed to address. In fact, most processes available from the research literature fall in the category of operations involved in the last row of business components, i.e., *production and maintenance processes*. As the level of involved resources moves into *oversight and management*, several interesting examples of *cases* may be found and used to illustrate the type of operations at play. Going further into *learning and innovation*, traditional contributions fade quickly or disappear entirely. Interestingly, the top row of Fig. 3 includes the 'strategy processe' that Van der Aalst and collaborators explicitly excluded from their foundational work in the early 2000's. A diversity of processes like those needed for controlling the quality of a cartoon in an entertainment industry enterprise, managing the pipeline of compounds in a pharmaceutical

[7]This is probably the only known actionable model derived from the general and powerful concepts running under the denomination of Resource-Based View (RBV) in the theory of the firm. Business process researchers are strongly encouraged to delve into RBV, search for cross-pollination with related Social Sciences work, and revisit business research topics such as those addressed in Organisational Behaviour schools.

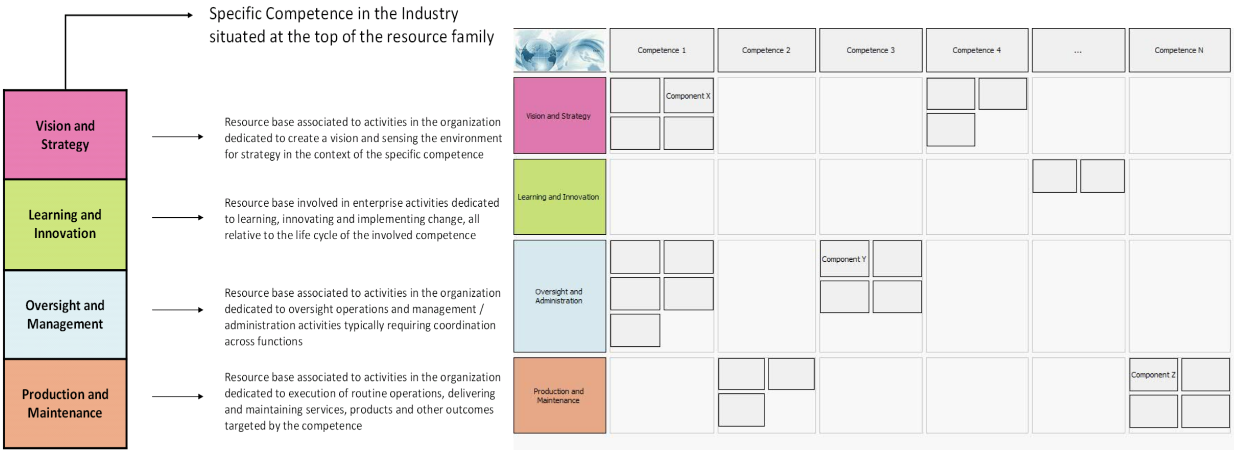


*Figure 3: The four types of resources defined according to the different forms of behaviour that are observed in a generic enterprise (left). Componentised organisation of such resources based on different competences (right). Each of these components deals with a number of core subjects (Nandi and Sanz 2013) whose evolution is key for the definition of corresponding competences (columns in the picture)*

company, and disseminating the learning harvested from a specific family of consulting practices throughout a services enterprise should not be included under the term 'strategy'. However, these *oversight and management* processes have not been addressed by the BPM tradition.

There may be still an argument that processes in classical BPM work aim at modelling operations *across the components and not inside them*, i.e., end-to-end processes also called '*value streams*' in some business literature. However, this argument does not necessarily follow from inspecting the work reported in more than one thousand papers in the last twelve years. The BPM tradition has adequately responded to the need of minimising transaction costs across the enterprise and builds upon existing governance mechanisms defined as true *systems of control* aligned with functions (Le Clair 2012). In that sense the traditional approach has followed closely the enterprise disconnection and rigidity leading to the present state-of-the-art in customer experience. Moving the foundational basis to address the next generation of business process (called "*hybrid connected processes*" in Le Clair (2012)), crossfunctional and complex processes (i) cannot be made or realised into workflow structures and (ii) new languages are needed to close the remarkable communication gap left in the cross-enterprise process space. It would be impossible to address these statements in full detail here but it should suffice to say that *loss of visibility* in cross-enterprise processes is a proven pain-point (Nandi and Sanz 2013) still yielding well-identified *performance* and *communication problems* in many firms. In other words, the "hundred of pages" alluded by Dietz (2011) are real and the insight that these many pages have unraveled is minimal.

From a research perspective and practical point of view, the reader is referred to the recent work in Nandi and Sanz (2013) for evidence that the main 'value streams' across an enterprise are in fact *progressions of core subjects* and not *life-cycle of objects*, at least when the latter is understood in the tradition of *statemachines*, i.e., artifacts evolving through a number of micro-states that separate the initiation and completion of "tasks". This fact goes back to the fundamental way metaphysics of processes has been approached in Social Sciences (Rescher 1996) and the conceptual duality between process and *subjects*[8] in the organisation of the world of a gen-

[8]The word "subject" here means "theme" or "topic". This

eric enterprise. Indeed, *subjects* are higher-level abstractions than conventional *objects* and their evolution is thus subjected to lots of asynchronous activity taking place across the enterprise. The delivery of outcomes produced by these asynchronous activities signals the completion of necessary results as agreed in pre-determined cross-functional *commitments*. These *commitments* are, in fact, a form of organisational contracts and may be regarded as quite granular macro-states in the evolution of an individual *subject*. These 'states' are called *milestones* in Nandi and Sanz (2013).

The need for aligning the research agenda in process to the main challenges faced by industry was also called out in the closing recommendations from the BPM study in Indulska et al. (2009): "*... despite being an actively researched field, anecdotal evidence and experiences suggest that the focus of the research community is not always aligned with the needs of industry*". A couple of years have elapsed since related papers were published but the situation has not changed much. Reijers et al. (2010) also addressed the importance of rooting BPM activities in industrial practice and correctly questioned the understanding of the actual adoption of BPM by organisations: "*... it may come as a surprise that contemporary insights are missing into which categories of organizations are adopting BPM and which type of BPM projects they are carrying out*". Actually, Aalst (2012) did some justice in his recent review of research in the last decade of BPM Conferences and highlighted that this work mostly addressed automation concerns. In particular, Van der Aalst revisited BPM systems as an opportunity to further position BPM tools as valuable instruments to build better software applications.

While this traditional BPM research work and practices should definitely continue, new market trends and needs from new enterprise capabilities in the Front-Office strongly suggest that business process focus has to shift in order to contribute to other urgent goals in organisations. Business process is called to play as a key instrument for achieving the *customer experience* needed in *front-office* operations and deep endtoend integration of the latter with the *back-office* in enterprises. The main motivation for the new work needed does not hinge around cost reduction, industrialising routine operations or building better software with BPM systems.

differs from the interpretation of subject as an actor carrying out an activity, and thus, it should not be confused with related semantics in S-BPM.

## 4 Back to Process Foundations

The evolution of business process has not happened without significant divergence and to some extent, also confusion. The state-of-the-art is plagued by language chasms, cultural silos and idiosyncratic viewpoints. Some of these challenges were documented in De Man (2009); Indulska et al. (2009); Recker et al. (2009); Reijers et al. (2010) and others. Reijers et al. (2010), state the challenge in clear terms: "*Considerable confusion exists about what Business Process Management entails ...*". Indeed, the definition of business process is still troubled by ambiguity and adding the term "management" has done little to clarify the confusion. A plea for this clarity has been articulated by Olbrich (2011): "*It seems a pity that a lot of current research fails to provide a basic definition of what underlying understanding of 'process' and 'BPM' it bases its work on*". In further exchanges in the same S-BPM conference, other authors such as Fleischmann (2011); Singer and Zinser (2011) agreed that the problem goes further into a lack of clarity on the very definition of BPM. A review of the literature shows that there is not a single and agreed definition of these terms. While "*... a scientific foundation is missing*" was clearly stated by Van der Aalst back in 2003, the review of BPM Conferences published by the author a decade later confirms that the fundamental shortfalls have not been overcome yet (Aalst 2012). The underlying reason is deeply related to the nature of business process being a *socio-technical system* and thus, its complexity cannot be approached by a narrow focus on technology dimensions. In Fleischmann's own words: "*... sociological systems like organizations are combined with technical systems like information and communication technology. For a holistic view of business process management we have to consider all aspects*" (Fleischmann 2011). Weske (2012) also highlights the deep nature of process: "*a business process consists of a set of activities that are performed in coordination in an organizational environment. These activities jointly realize a business goal.*" While using different language, other authors also defined business processes (Davenport 1993; Debevoise 2007; Dumas et al. 2013; Indulska et al. 2009; Krogstie et al. 2006; Ould 1995a; Smith and Fingar 2007 and the list goes on).

The Object Management Group recognised the foundational problem with the definition of process. Siegel (2008), the leader of the BPM group stated: "*there is no agreed-upon industry definition of Business Process. Instead, there are multiple definitions, each looking at the field from its own unique point of view, concentrating on its own set of concerns*". Certainly, it is not a matter of one definition being right and the others being wrong. Rather, the issue is about the varying points of view used. As a consequence, the main efforts in process modelling standardisation have not yet yielded the expected outcomes, as discussed in Recker et al. (2009), more broadly exposed in Indulska et al. (2009) and highlighted in Aalst (2012). Unquestionably, most people do have a similar and informal notion of "business process". But this intuitive agreement does not mean a convergence across viewpoints. In fact, the variations in the definition of process may suggest that the term is a *boundary object* across disciplines, individuals from different units of an organisation or communities of practice. Other researchers in Social Sciences and Philosophy have also focused extensively on the concept of process and its definition. Ven (1992) addressed the topic in the context of one of the most complex types of processes in organisations, i.e., the strategy process. The depth of Van de Ven's classification reveals the foundations underlying many business process definitions. In spite of having been published two decades ago, this work has gone unnoticed in most of the BPM literature (Aalst 2012; Aguilar-Savén 2004; Klein and Petti 2006; Ko et al. 2009; Lu and Sadiq 2007; Ould 1995b; Propp 1968; Toussaint et al. 1998; Trkman 2010 and many others).

Another language chasm across different schools of thought or communities of practice is the unclear relationship between the concept of business process and that of *organisational routine*. Rich literature is available on the study of routines (Becker 2004), the significance of routines as a unit of analysis for organisations (Levin 2002; Pentland and Feldman 2008; Pentland et al. 2012) the collectivist meaning of routines and the need for establishing solid micro-foundations (Felin and Foss 2004) among others. It is very likely that business process and routine address identical concerns in organisation theory; however, in spite of the prolific technical production in the two subjects during decades, their formal relationship and the reasons for keeping two different terms remain unclear.

More recently, there has been a fundamental piece of work in process that builds upon a reconciled view of process and information available since the early days of the Information Engineering schools in Europe. This approach to business process goes under the brand of *entity-centric operations modelling* (Sanz 2011) and offers a holistic approach that reunites different types of processes under the same conceptual understanding. This entity-centric concept has been used intensively by (Ould 1995a,b) and although the notion of life-cycle is from the early 1980's, several important contributions has been made in different industries and software to merit a detailed inspection in Business Process Engineering (Bhattacharya et al. 2009; Cohn and Hull 2009; Nandi 2010; Nigam and Caswell 2003; Robinson 1979; Rosenquist 1982).

Quite interestingly, another related approach was recently presented to model cross-functional end-to-end processes in enterprises based on the notion of *subjects* and *nexus* of *commitments* (Nandi and Sanz 2013). The foundation for all this work appears as an important step toward the design and construction of different process types, including the so-called *value streams*, by using a common approach in which information does not take back seat as a mere "after-thought" in the modelling of behaviour or becomes confused with "state model", being the latter a common misunderstanding incurred by most computer scientists as Van der Aalst remarkably noted. The point of reunion of these seemingly related modelling techniques does not reside in "artifacts" or "object life-cycle" but instead, it goes back to the Social Sciences in the sense that the unifying concept is the very epistemology of process, i.e., "things in the making" (Tsoukas 2001; Tsoukas and Chia 2002). Consequently, process design is about describing *the evolution of a core subject*. While the roots of this approach come from several decades of work and different schools of thought, not all process researchers and practitioners seem familiar with these concepts and related literature sources.

## 5 Research topics in Business Process Engineering

It would be difficult to propose here a complete agenda of research and practice in Business Process Engineering. Like in any other emerging field of work, only the pass of the time, community activities and market consolidation will determine its boundaries and shape its ultimate priorities. However, based on current work and ongoing industry needs, it would be safe to highlight some important areas with the purpose of stimulating further research.

This is a first pass through such a list. Topics are classified according to four basic categories:

*Customer-Enterprise Behaviour: Foundations and Models*

**(A)** Establish a foundation for understanding and modelling the *journeys* that customers follow in their multiple touchpoints when interacting with enterprises across different channels. These journeys are probably the most looselycoupled type of processes, i.e., they are highly unstructured but they are not "random walks" at all as customers seek for specific outcomes. This type of interactions is also found in other collaborative work in enterprises (Harrison-Broninski 2005). In addition, as involved interactions combine and alternate human-to-human and human-todigital contacts, these journeys are rich in information and behaviour. Then, their adequate understanding is imperative for the next generation of customer experience. Some work has been done on this topic but there are no foundations yet with a theory that explicates the journeys and how behaviour of the actors should be guided from footprints of customer contacts and previous experiences. This is one of the most fundamental research problems that different industries need to benefit from as its value is directly related to customer loyalty.

**(B)** Discover customer-enterprise co-creation mechanisms and have them reach a massive scale through innovative processes. This will support the social transformation necessary for the information coming from social data to become a **trustable source of actual behaviour and intent of individuals**. While social media means a flood of useful data, inferring human intention and behaviour from these sources remains illusory. *Co-creation processes* deploying collaborative and mutually beneficial practices appear essential for the next generation of customer experience. Explicit provision of knowledge on an individual could be then done in exchange for personalised services or some other form of tangible value-propositions. This will lead individuals to provide trustworthy evidence of their behaviour and intent. Designing and implementing the necessary processes to reach the scale needed requires deep socio-technical innovation. These processes will also help encourage full transparency from consumers and enforce accountability from companies. The latter will help replace today's legal disclaimers in which consumers are asked to resign their privacy rights under terms-and-conditions that probably few consumers read and even a fewer number of them understand.

**(C)** Create a "sociology of the customer" that helps understand the effect of using mass processes even with individualised clients in the pursuit of 'profitability'. If economic analysis renders it viable, data footprints left by consumers will not be the only hint to infer customer behaviour (which is an erroneous approach to understand people's needs and true expectations anyway). Furthermore, the integration of process and big data will allow for full operationalisation of "insight", thus making the latter move from "interesting discovery" to a Social Science-supported theory to enhance services and provide enterprises with higher customer equity.

*Front-Office Business Architecture*

**(D)** Propose complete Front-Office operational models that represent the actual work enterprises do with and for their own customers. This should include *process and performance frameworks* for *all* those key competences and capabilities in the enterprise that belong to the Front- Office operations. In particular, the creation of solid Process Reference Architectures for emerging operational areas in marketing, brand management, campaign management, etc. would be critical for accelerating industry value of new research. As suggested earlier in this paper, surfacing and documenting these new workpractices is essential. Software packages are already in the market and these applications bury important processes whose frequent change is imperative for flexibility of Front-Office operations.

**(E)** Reconcile the ever-deepening silos of Information and Process. As suggested by the different levels shown in Fig. 4, the information and process domains have traditionally evolved in almost complete isolation from each other. As damaging as this disconnection may result for the well-being of any organisation, the problem has stayed unresolved throughout several decades. In fact, the gaps have widened and got deeper as the new "business analytics" trend has been getting momentum in enterprises and gathering the attention of the Chief Marketing Officer. The introduction of "big data" and other marketing concepts in Information Management technology has continued to widen the chasm. Hopefully, by building on a new foundation where the Information Process in organisations and society is repurposed as a single phenomenon through Business Informatics, new bridges will be built across the two silos. This reunion is dubbed "*Deep Process meets Business Analytics*" on Fig. 4. The need for this integration will reposition "process analytics" as the integration of on-line (real-time) analytics and customer journeys.

**(F)** Provide data-only analytics and related statistical modelling with a better foundation through behaviour-based causation. This should help foster a blended approach through "white box" Enterprise Engineering modelling for today's decision-making techniques based on "black-box" statistics. Among other areas of critical enterprise value, this topic should also help define an enterprise business performance framework that integrates behaviour and data in organisations. This goal corresponds to achieving the important integration shown in the top level of Fig. 4.

**(G)** Develop a theory of Process Modularisation that is consistent and evolvable with change. This work has been initiated by different colleagues in (Nuffel 2011). As the "unit of change" in Process gets progressively more clear, the topic of Process Evolvability will also become connected to modularisation, thus addressing

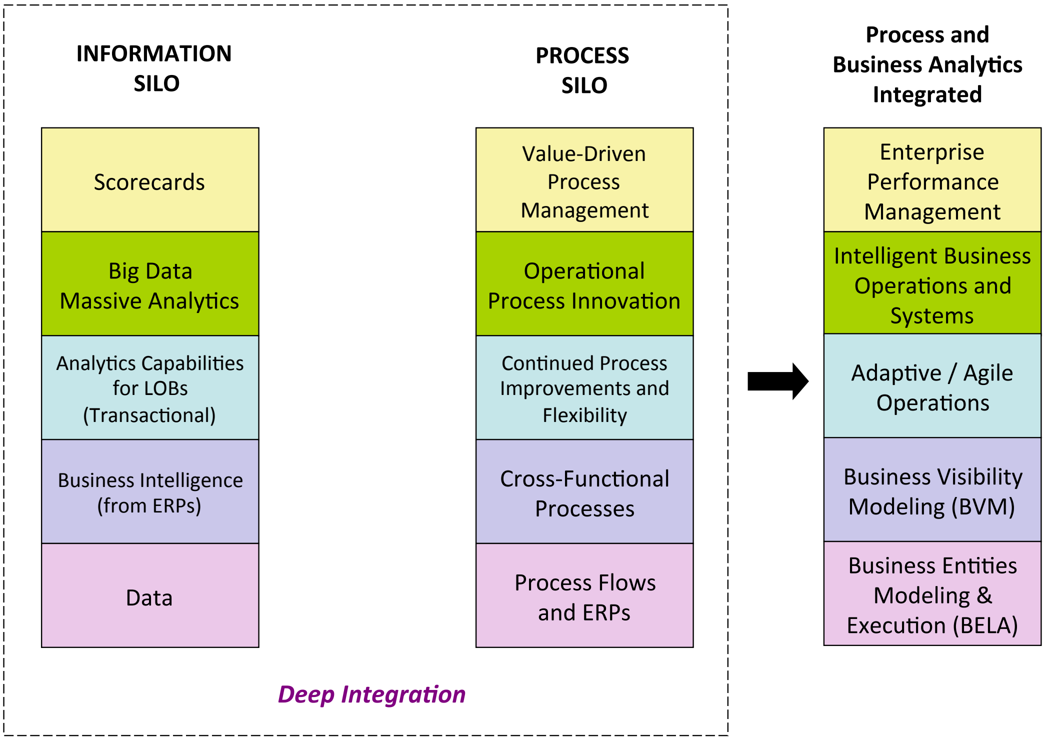


*Figure 4: Silos in information and process management have deepened with the evolution of each domain. This gap is more notorious after the advent of business analytics, scorecards, performance management and value-driven process BPM*

the need for managing combinatorial effects (as already addressed by the general principles of Normalised Systems Theory in (Mannaert and Verelst 2009) for the case of software systems).

**(H)** Clarify the distinction, if any, between the Social Science concept of *organisational routine* (Pentland et al. 2012) and the broader meaning of process coming from Business Process Engineering. This will help reconcile work across the different schools of research in Social and Computer Sciences. While practitioners seldom use the word "routine" (and when they do, they imply repetitive or boring tasks which is not the meaning in Social Sciences), it is important to benefit from cross-insemination between Enterprise Engineering and Social Science research for better understanding of organisational design through deep behaviour research.

**(I)** Benefit from Enterprise Engineering principles to reposition the role of humans in the value-creation of Front-Office business areas. This topic has several deep social connotations and should include the provisioning of economic evidence of the scalability (or lack thereof) of human-centric methods for understanding individual behaviour of customers.

*Industry-Oriented Content*

**(J)** Create industry-specific multi-channel customer journeys for key services industries such as banking, insurance, retail and telecommunications. Link to and support these customer journeys with knowledge-based representations that bridge process and knowledge management. This is a significant area of work that will pave new integration of Process with Knowledge Management by creating a *customer-centric knowledge-based organisation of* *the enterprise*. The meaning of the latter statement is about making all pertinent information from an enterprise to be organised and be made available to customers in new, intelligent ways in which "process footprints" serve as a historical base to reorganise and find information personalised to individual customers (this comment comes from a private communication with P. Nandi).

*Tooling*

**(K)** Propose new tools that further the current state-of-the-art of Information Technology for process design and construction in the concert of a Business Process Engineering approach (in this connection, the generation of code is a secondary concern but flexible and open endtoend integrated capabilities would be a breakthrough). These process tools will be the carrier of data analytics in real-time while supporting the delivery of personalised services to individual customers.

## 6 Conclusions

Business Process has left the productivity corner where it has been confined by "scientific management". With the advent of customer-enterprise interactions of all forms and exercised through multiple channels, the need for a significantly improved customer experience is an imperative in transforming front-office operations. Conventional approaches to process have proven to have a devastating effect on loyalty. Renewed research and professional efforts to approach process as part of complex social systems are a must to cope Fig. 4. Silos in information and process management have deepened with the evolution of each domain. This gap is more notorious after the advent of business analytics, scorecards, performance management and value-driven process BPM with the challenges faced in those competences of enterprises dealing with customers, particularly in the business-toconsumer industries. Business Process Engineering is a new domain of work that attempts to make the past IT-centric view of process into a multidisciplinary area of both institution and practice knowledge.

## 7 Acknowledgements

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# Service Innovation for the Digital World

*The foundational principles and conceptual building blocks of customer-centric service innovation (SI) practice are explained, and a resultant integrated framework of SI design practices for customer value co-creation is synthesised. The nexus of service strategy, service concept and business model is identified to assure SI commercialisation. The requisite SI models and processes to systematise the innovation practice are reviewed. The emergent practices of customer and community participation, in a digital world, across the firm's entire SI lifecycle are explicated, together with the requisite strategic management practices for successful service innovation.*

## 1 Introduction

Service innovation – the art and science of creating innovative services that customers value and are willing to pay for – in the digital world exemplifies many of the fundamental challenges of business informatics. Recent studies of service innovation have focused on the effective management of service innovation to enhance firm performance – such as the importance of managing inter-organisational relationships and commitments (Eisingerich et al. 2009), the antecedents and consequences of service innovation (Ordanini and Parasuraman 2011), and a preliminary service-thinking framework for value creation (Hastings and Saperstein 2013). These studies have shown that success in service innovation requires "service thinking" (and attendant service culture) and is contingent on effective collaboration with the firm's customers and partners in the overall innovation process. These authors also concur that service innovation is about the creation of customer value (Grawe et al. 2009). However, the art and science of designing and managing service innovations, especially for the digital world, remains an under-explored research area. This paper seeks to contribute to filling this void by exploring the extant literature to identify the critical constitutive theories and practices that would lead to successful service innovation in line with Eisingerich et al. (2009); Hastings and Saperstein (2013); Ordanini and Parasuraman (2011). It focuses, in particular, on the various critical roles of customers in value co-creation for themselves in conjunction with the service provider and their network of partners.

The paper is structured as follows. Section 2 describes in detail the fundamental building blocks of service innovation: service dominant logic, service systems, operant resources and dynamic capabilities, value networks, and finally, customer value co-creation – the ultimate purpose of service innovation. Section 3 synthesises from the extant literature a framework of design practices for service innovation, comprising four business strategy-aligned interrelated practices of service conceptualisation, service design, customer experience and value creation, and service architecture which, collectively, are typically pursued by designers iteratively (experimentally) and holistically. Section 4 links the design practices framework to service strategy on one hand and business model design on the other to address the commercialisation aspect of service innovations. Section 5 reviews, individually, the common and foundational service innovation functional models (in terms of the 'scope' of and the 'competence-based approach' to service innovation) and processes (in terms of new service development) for the creation of customer value.

Section 6 and Sect. 7, respectively, review the increasingly important 'open innovation' practices of involving customers and online community in the end-to-end service innovation process in the digital world, while Sect. 8 addresses the requisite strategic management capability to ensure service innovation success. Finally, Sect. 9 concludes the paper by summarising the requisite principles (theories) and service design and innovation management practices for service innovation excellence.

## 2 Conceptual Building Blocks

### 2.1 Service Dominant Logic

In the early days (pre-1980) of services marketing, services were seen as a special kind of products. Seen as a unit of production output, services were defined as residues of, and thus subordinate to, products (Lovelock and Gummesson 2004; Vargo and Lusch 2004). From this goods production perspective, services as an output are seen to possess four so-called IHIP characteristics which are distinctly different from physical products: Intangibility, Heterogeneity, Inseparability and Perishability (Lovelock and Gummesson 2004). Intangibility refers to the services output as being intangible. Heterogeneity refers to the services possessing variable input resources and performance outcomes. Inseparability refers to the production and consumption of services occurring simultaneously. Perishability refers to the services output as being non-durable and non-storable. However, these services characteristics were actually shown to be not generally applicable to all services (Lovelock and Gummesson 2004). Leading service scholars around the globe also regard the production-oriented IHIP view as outdated (Edvardsson et al. 2005), because it fails to capture the processual, interactive and relational nature of service co-creation and consumption as seen from the customer perspective (Edvardsson et al. 2005; Fitzsimmons and Fitzsimmons 2010). This alternative customer-centric and relational view constitutes the service-dominant logic (S-DL) which defines service as a process of applying the competencies and skills of a provider for the benefit of, and in conjunction with, the customer (Vargo and Lusch 2004, 2008). A service offering is produced using the firm's resources including both tangible (such as goods) and intangible (such as knowledge, competence and relationship) assets (Arnould 2008). The value characteristics of the service provisioned, however, are co-created through the interactions of the client's competences with that of the service provider (Gallouj 2002). Thus the client is active in a service interaction; it co-creates value (for itself) with the provider (Fitzsimmons and Fitzsimmons 2010; Gadrey and Gallouj 2002; Gallouj 2002). The central idea of S-D logic is that "exchange is about the process of parties doing things for and with each other, rather than trading units of output, tangible or intangible" (Vargo and Lusch 2008).

### 2.2 Service Systems

Service systems are the basic unit of analysis of (the customer-centric view of) service (Maglio and Spohrer 2008). A service system is defined as a complex adaptive system of people, and technologies working together to create value for its constituents (Spohrer et al. 2007). For example, a telecom company is a complex market-facing technology-based service system. The study of service systems is focused on creating a basis for systematic service innovation (University of Cambridge and IBM 2007). It requires a multidisciplinary integrative understanding of the ways organisation, human, business and technology resources and shared information may be combined to create different types of service systems; and how the service systems may interact and evolve to co-create value (Maglio et al. 2009). A service system has a service provider and a service client or beneficiary (Maglio et al. 2006). Service systems are connected by value propositions (Maglio et al. 2009). IT or business process outsourcing service configurations negotiated and agreed to between service providers and clients are examples of service systems. Consistent with S-DL, value-cocreation interactions between service systems are service interactions, each comprising three main activities: proposing a value-cocreation interaction to another service system (proposal); agreeing to the proposal (agreement); and realising the proposal (realisation) (Maglio et al. 2009).

Service systems are dynamic, constantly composing, recomposing and decomposing over time. A service system operates as an open system capable of improving the state of another system through sharing or applying its resources (including competences/capabilities), and improving its own state by acquiring external resources (Maglio et al. 2009). Thus, service systems engage in knowledge-based interactions to co-create value, where value is derived and determined in use – the integration and application of resources in a specific context embedded in firm's output – and captured by price (Vargo et al. 2008). Consequently, advances in service innovation are only possible when a service system has information about the capabilities and the needs of its clients, its competitors and itself (Maglio et al. 2009).

Integral to and as a consequence of service innovation, service systems co-create value through collaboration and adaptation, and establish a balanced and interdependent framework for systems of reciprocal service provision. Service systems survive, adapt, and evolve through exchange and application of resources (especially knowledge and skills -operant resources as explained below) with other systems (Vargo et al. 2008).

## 2.3 Operant Resources & Dynamic Capabilities

A resource is called an operand resource (i.e., tangible physical resource) "on which an operation or act is performed to produce an effect", or an operant resource (i.e., intangible knowledge-based capability) "which acts on other operand or operant resource to produce an effect" (Vargo and Lusch 2004). Operant resources are dynamic, which include competences or capabilities that can be nurtured and grown in some unique ways to provide competitive advantage to firms (Madhavaram and Hunt 2008). Operant resources that are valuable, rare, inimitable and not substitutable will generate sustainable competitive advantage for firms. For example, market orientation – i.e., market sensing and customer linking capabilities – is an operant resource that would create that advantage (Arnould 2008). This motivates firms to create and use dynamic operant resources to sustain the competitive advantage.

Highly innovative firms possess "masterfully developed" operant resources accumulated over a long period from institutionalised learning practices (Madhavaram and Hunt 2008). These resources allow the firm to effectively manage coevolution of knowledge, capabilities, and products or services to sustain its competitive advantage. Collaborative competence is identified as a pivotal operant resource for sustained service innovation (Lusch et al. 2007) – one that assists in the development of two additional meta-competences: absorptive competence, and adaptive competence (also collectively known as dynamic capabilities (Teece 2007)) which enable the firm to, respectively, absorb new knowledge and information from partners, and adapt to the complex and turbulent environments by reconfiguring its resources (and organisational capabilities) with those of the external partners. These operant resources are key components of a service system which is conceptualised as a resource integrator (Spohrer et al. 2007). It is the people's unique knowledge and skills and dynamic capabilities that make service systems adaptive to and sustainable with the changing market environments (Spohrer et al. 2007; Teece 2007; Vargo et al. 2008).

## 2.4 Value Networks of Digital World

In the increasingly digital world, information technologies are "liquefying" physical assets into information resources, and transform a service firm into a value-creating service system in which a constellation of economic actors (customers, suppliers, business partners and the like) are able to seamlessly collaborate to co-create value (Normann and Ramirez 1993). This reflects the S-D logic's commitment to explicating the firm's collaborative processes with customers, partners, and employees to engage in the co-creation of value through reciprocal service provision (Lusch et al. 2007). And the customer is regarded as an operant resource – a dynamic resource that is capable of acting on other resources to create value for itself (Vargo and Lusch 2008).

With the ubiquitous digitalisation, goods are increasingly being embedded with microprocessors and intelligence and becoming versatile platforms for service provision with enhanced customer and supplier insights and superior self-service ability. It also reduces transport and communications costs, enhances the ability to interact directly with customers and suppliers and consequently coordination between firms becomes more efficient and responsive (Lusch et al. 2009). Thus, the firm will become an essential service provisioning agent (actor) in a complex and adaptive value network comprising a spatial and temporal structure of loosely coupled value-proposing social and economic actors. The actors interact through institutions and technology capable of spontaneously sensing and responding via their dynamic capabilities to co-produce service offerings, exchange service offerings, and finally co-create value. They are linked together by means of competences, relationships, and information (Lusch et al. 2009). The relationships are collaborative and guided by non-coercive governance. This implies voluntary, reciprocal use of resources for mutual value creation by two or more interacting actors, through the symmetric exchange of information and resources (competences) (Vargo et al. 2008). So in the value network, customers and suppliers become partners, and competitors become collaborators as well (Chesbrough and Davies 2010). Each firm (actor) operates as an open system (Maglio et al. 2009). Firms must practice open innovation (Chesbrough 2003) and develop systems integration capability (Chesbrough and Davies 2010) as part of its dynamic capabilities (Teece 2007) to integrate the requisite competences and resources from external sources with their own to co-create value; e.g., Apple's creation of the iPod/iTune music service.

Value co-creation and innovation in the digital world would require firms to institute individualised and immediate customer feedback (to and from the customers) to engender customer and organisational learning (Johannessen and Olsen 2010). This requires a new IT-enabled organisational logic which encompasses modular (multi-sourcing) flexibility, front-line (customer learning) focus, IT-enabled individualisation and "connect and develop" innovation practices (Chesbrough and Davies 2010; Johannessen and Olsen 2010). In addition, the firm needs new cooperation structures by partaking in global competence clusters and practising coopetition (Johannessen and Olsen 2010). Above all, to be agile and adaptable as they learn of changing customer needs, firms need to develop dynamic operant resources – the dynamic capabilities (Teece 2007). The dynamic capabilities allow firms to continually align their competences to create, build and maintain relationships with (thus the value propositions to) customers (the ultimate source of revenue) and suppliers (the source of resource inputs).

### 2.5 Customer Value Co-creation

Customer is at the heart of value creation and service is about relationship with the customer (Edvardsson et al. 2005). The customer interacts with the service provider via the interface through which information /knowledge, emotions and civilities are exchanged to co-create value (Gallouj 2002). Value is wholly determined by the customer upon, and in the context of, service usage (and customer experience), in which the competence (operant resource) of the provider is integrated with the competence (operant resource) of the customer to (perform 'a job' to) create (business) value with the customer (Edvardsson et al. 2005; Vargo and Lusch 2008). The service provider cannot deliver value, but only offer value propositions (Vargo and Lusch 2008). To win the service game, the value proposition must consistently meet the customer expectations and behavioural needs (Schneider and Bowen 2010). This can be assured by co-opting the customer competence in co-creating the service offering with the provider (Prahalad and Ramaswamy 2000) – e.g., user toolkits for innovation (Hippel 2001). However, the customer would collaborate with the provider in co-creation of core service offerings only if they would gain benefits, such as: expertise, control, physical capital, risk taking, psychic benefits, and economic benefits (Lusch et al. 2007).

Service innovation must therefore be concerned with effectiveness of value co-creation between the provider and beneficiary. It recognises the principle that a proposed value by the provider, in the context of the client, is actually a composite of benefits and burdens (or costs), which can be evaluated using a customer value equation (Fitzsimmons and Fitzsimmons 2010). Burdens relate to the service's usability (or its relative ease-of-integration with the client's resources or activities to "perform the job the service is hired to do") – the more user-friendly it is the less the burden and the greater the user experience; and the greater the customer efficiency (Xue and Harker 2002). Thus, the most compelling service with the best "value for money" to the client is one that has the largest "benefit-to-costs" ratio. This suggests that user involvement in co-creating the service offerings (or co-designing the value propositions) with the provider would more likely create 'fit-for-purpose' service for the client and thereby maximising the benefit.

Service firms must therefore "consider not only the employees' productivity but also the 'productivity' and experience of the customer" (Fitzsimmons and Fitzsimmons 2010; Lusch et al. 2007; Schneider and Bowen 2010; Womack and Jones 2005). From a service system viewpoint, value, created as a result of integrating the provider's resources with the client's, increases the client system's adaptability and survivability to fit with its changing environment (Vargo et al. 2008).

## 3 Framework of Design Practices

To create innovative services that sustainably co-create superior customer value in the constantly evolving value networks of the digital world, a design framework is synthesised from the extant literature consistent with the preceding conceptual building blocks. The design framework for service innovation consists of closely interrelated practices of: (a) service concept which defines what the service is and how it satisfies customer needs, (b) service design which defines the service delivery mechanisms to consistently satisfy customer needs, (c) customer experience and value creation which guides service design to align the provider's competences and learning regime to those of the customers to ensure superior experience, and (d) service architecture which systematises service design and innovation. These four interrelated practices are detailed below individually, but are typically practised in the real-world iteratively and holistically.

### 3.1 Service Concept

A service concept defines the conceptual model of the service. It describes what the service is and how it satisfies customer needs (Bettencourt 2010). Service concept is the most critical component of service strategy, and reflects the alignment of the customer needs (job and outcome opportunities) with the company capabilities. Service concept also forms the fundamental part of service design, service development and service innovation (Fynes and Lally 2008). It is developed as the end-result of the activities of strategic positioning, idea generation and concept development/refinement. The conceptual model of a service consists of seven components which together define the desired customer outcomes (value propositions) of the service: service benefits, participation activities, emotional component, perception component, service process, physical environment, and people/employee (Fynes and Lally 2008). To define an innovative service concept, Bettencourt (Bettencourt 2010) recommends that a service firm should: focus creative energies on specific job and outcome opportunities; identify where the key problems lie in satisfying high-opportunity jobs and outcomes; systematically consider a diverse set of new service ideas to satisfy the opportunities; and build a detailed concept with service strategy and service delivery in mind.

Service concept is the principal driver of service design decisions at all levels of planning and implementation. It relates to service architecture or service blueprint which guides service design, and to service governance which defines the decision rights and the decision making process for service design, planning and implementation (Goldstein et al. 2002). For example, at the strategic planning level, the service concept drives design decision for new or redesigned services. At the operational level it defines how the service delivery system implements the service strategy and how to determine appropriate performance measures for evaluating service design. At the service recovery level, it defines how to design and enhance service encounter interactions. Thus service concept is the common foundation for new service development, service design and service innovation. For instance, service concept development and testing is at the heart of service design in new service development. Central to service conceptualisation is declaring what the customer value proposition is in relation to the firm's strategic intent, how it meets the customer needs and what is the service logic required in delivering the value proposition (Goldstein et al. 2002). Service concept articulates the service operation – why and how the service is delivered; the service experience – i.e., customer's experience; the service outcome – i.e., customer benefits; and the service value – i.e., the perceived customer benefits minus the service cost (Clark et al. 2000). Service concept and the corresponding service design (described below) are intended to reflect the service firm's business strategy and therefore directly impact the firm's financial performance. From the perspective of service innovation (or new service development) process (detailed in Sect. 5.2) service concept is developed in the "Create Ideas" phase and selected for design in the "Evaluate and Select Ideas" phase (after experimentation), while the corresponding service design is developed in the "Plan, Design Develop and Implement Ideas" phase. However, in the digital world, the innovation process would tend to be circularly iterative akin to "agile (emergent) development" as opposed to a purely linear (predictive) manner.

### 3.2 Service Design

Service design starts with the customer/user and defines how the service will be performed using human-centred and user-participatory methods to model the service performance (Holmlid and Evenson 2008). A service is conceptualised as an open system with customers being present everywhere. Service design must address strategic service issues such as marketing positioning and the preferred type of customer relationship, in line with the strategic intent of the service organisation. Service governance is also required to monitor the service qualities and financial performance against the design outputs. The framework for designing the service delivery system must address multiple interrelated factors: standardisation; transaction volume per time period; locus of profit control; types of operating personnel; types of customer contacts; quality control; orientation of facilities; and motivational characteristics of management and operating personnel (Goldstein et al. 2002). The service delivery system fulfills the firm's strategic service vision and is designed/specified by means of service blueprinting (Bitner et al. 2008; Fitzsimmons and Fitzsimmons 2010). Service blueprinting is a map or flowchart of all the transactions constituting the service delivery process. The map identifies: the potential 'fail-points'; the line of interaction between client and provider known as service encounters; the line of visibility – above it employees actions are visible to the customer (directly affecting customer experience); below it is the 'back-stage' ; and the internal line of interactions below the line of visibility (Bitner et al. 2008; Fitzsimmons and Fitzsimmons 2010). The service encounter design is a critical element of service design, because from the customer's viewpoint "these encounters ARE the service" (Bitner et al. 2008). The design focuses on maximising the quality of 'service experience' by the customer. However, service experience is the result of the combined efforts of the 'back stage' information and processes and the 'front stage' customer handling – both must work seamlessly in unison in satisfying the customer request (Glushko and Tabas 2009).

Taking an end-to-end view of service process allows designers to analyse the stakeholders' requirements, pain points and performance metrics from which service design (or redesign for an existing service) could be developed in collaboration with the stakeholders incorporating a combination of changes across process, organisation, technology, and tool in an integrative manner (Maglio et al. 2006).

Service encounter design is guided by the possible relationships between the three parties in the service encounter: the service organisation (whether to pursue a service strategy of efficiency (cost leadership) or effective (customer satisfaction) or both); the contact personnel (following strict rules/order or empowered with autonomy and discretion); and the interaction between contact personnel and the customer (balancing conflicting "perceived control" by both parties) (Fitzsimmons and Fitzsimmons 2010). Technology could be designed into the service encounter in four ways: (a) technology-assisted service encounter – only the contact personnel has access to the technology; (b) technology-facilitated service encounter – both the customer and the contact personnel have access to the technology; (c) technology-mediated service encounter – the customer and contact personnel are not physically co-located and their interaction is mediated through the (online) technology; (d) technology-generated service encounter – i.e., self-service, the contact personnel is completely replaced by technology (Fitzsimmons and Fitzsimmons 2010; Froehle and Roth 2004). Thus technological innovation in services could require a change in customer role in the service delivery process. Therefore it is critical to take into account the potential customer (as well as employee) reaction to the new technology in the design phase to avoid future problems of acceptance (Fitzsimmons and Fitzsimmons 2010).

Service design must include strategies for handling service variability to ensure sustained level of service quality expected by customers (Glushko and Tabas 2009). For instance, to manage an unexpected deviation from normal service encounter, the service design (per service strategy and governance) may incorporate the notion of service personnel 'empowerment' which grants them the discretion to recover from service deviation (failure) by offering 'compensations' or alternative solutions to the customer to minimise adverse impacts to the customer (Glushko and Tabas 2009). Moreover, where multichannel services are provided, the design must ensure consistent service experience across all channels. Finally, service design needs to incorporate the requirements of lean consumption (Womack and Jones 2005) and achieve the objectives of service profit chain (Heskett et al. 2008).

Design of a service system (which offers the service) similarly must address the roles of people, technology, shared information, as well as the role of customer input in production processes and the application of competences to benefit others. The design must also address the service systems' requirements for agility and adaptability in alignment with their environments (Spohrer et al. 2007). A learning framework is necessary to sustain the firm's creative design ability, and improve and scale the service systems. The framework is designed to achieve three critical requirements: effectiveness – the right things get done; efficiency – things are done in the right way; sustainability – the right relationships exist with other service systems to ensure the system's long term sustainability (Maglio et al. 2009; Spohrer et al. 2007). Sustainability is achieved through the service system's (brand) reputation, because excellent reputations naturally attract value propositions from other service systems wanting to co-create value. It also requires appropriate amount of shared information to be available to all service systems (the principle of information symmetry) to enhance coordination and mutual sustainability within the service ecosystem. The design is however inherently challenged by the people factor, as people are complex and adaptive.

In sum, service system design, broadly, must address four variables: physical setting; process design – the service blueprinting or mapping which designs 'quality' into the service delivery system; job design – the social technical job design which include addressing the employee motivational requirements; and people – the staff (competence) selection (Goldstein et al. 2002).

### 3.3 CustomerExperience & Value Creation

Customer experience requirements of each service type are usually analysed using use-case scenarios similar to that of service blueprint (Bitner et al. 2008; Patricio et al. 2008). Customer experience is influenced by the service intensity, which is defined in terms of the number of actions initiated by the service provider, or the amount of information exchanged in a service encounter or the duration of the service encounter (Glushko and Tabas 2009). The service design of multi-interface system must unify service management, human computer interface, and software engineering perspectives into an integrated design embodying the customer experience requirements (Patricio et al. 2008).

Service organisations are increasingly managing customer experiences to promote differentiation and customer loyalty. The experience-centric service providers design the activity and context of the experience to engage customers in a personal, memorable way. The experience design must address the dynamic and ongoing engagement process between customers and the service organisation. The engagement can be emotional, physical, intellectual, or even spiritual, depending on the level of customer participation and the connection with the environment (Zomerdijk and Voss 2010).

Customer value creation process is a dynamic, interactive, non-linear and often unconscious process (Payne et al. 2008). Value is in the context of the performance outcome of the customer's resource integration practice. To ensure optimal value co-creation, the three contiguous processes: the customer value-creating processes; the supplier value-creating processes and the interfacing service encounter processes must all be aligned (Payne et al. 2008). The customer experience is a culmination of the customer's cognitions, emotions and behaviour during the relationship with the supplier. These elements are interdependent and involve the customer in thinking, feeling and doing – leading to customer learning – in the process of value co-creation (Payne et al. 2008). Indeed, a recent study by (Helkkula et al. 2012) showed that "value in the [customer] experience [is characterised] as an ongoing, iterative circular process of individual, and collective customer sense making, as opposed to a linear, cognitive process restricted to isolated service encounters." (p.59) More research is required on "the need for appropriate metrics for the cognitive and emotional demands" of customer experience imposed by different service interaction designs (Glushko and Tabas 2009).

### 3.4 Service Architecture

Service architecture is conceptualised to systematise service design and innovation. Leveraging concepts from product architecture, service architecture aims to create a common language (comprised of nodes and linkages) across different views on service design and a systematic way to operationalise and measure the degree of service architecture modularity (Voss and Hsuan 2009).

Service architecture is constituted in accordance with the principle of modularity, which in turn is characterised by five dimensions: components and systems as the basic modular units, the interfaces, degree of coupling, and commonality sharing between components, and platform as the overarching configuration of components and interfaces that makes up the product/service architecture (Fixson 2005). Modularity refers to the degrees by which interfaces between components are standardised and specified to allow for greater re-usability and sharing of (common) components among product/service families. It provides the basis for mixing and matching of components to meet the mass-customisation requirements; yields economies of scale and scope, and can help structure products/services to facilitate outsourcing. Platform strategies are the vehicles for realisation of mass customisation (Fixson 2005). As platform decisions often cut across several product/service lines or divisional boundaries, platform strategic decisions must belong in the top management team who need to and can resolve cross-functional conflicts to jointly-achieve the firm overall strategy.

An important and challenging aspect of service architecture is the interface. Interfaces in services can include people, information, and rules governing the flow of information. Service interface can also include the flow of people. In general, an active role in service customisation would be played by both the front-end employees and the customers themselves. This would suggest the service components need to be more loosely coupled than product components (Roth and Menor 2003).

A service system can be analysed, for the purposes of service architecture, in terms of four levels of increasing details in specification: industry level, service company/supply chain level, service bundle level, and service package/component level (Voss and Hsuan 2009). At level 0, the industry architectural template defines the value creation and the division of labour as well as value appropriation and the division of surplus or revenue among the different players. At level 1, the service company and its supply chain(s) are modelled both upstream and downstream. Both shared (internal cross-functional) and outsourcing of service components are important consideration for the service company level for economic and resource flexibility reasons, in line with its business strategy. At levels 2 and 3, the service concept and service design activities of service innovation practice are harmonised and integrated to assure service agility. At level 2, the individual service bundles of the service offering at the company level are analysed – each bundle is viewed as a set of modules of service delivery, comprising the front- and back-office functions (and associated capabilities). At level 3, the service package and component level, the characteristics of the building blocks (components) are specified that contribute to the overall systems architecture, namely: standardisation, uniqueness, degree of coupling and replicability (Voss and Hsuan 2009). Thus, service architecture enables service agility as new services can be provisioned with minimal cost and little internal change, and the architecture can be dynamically adapted in response to external stimuli. But this would require support by a corresponding modular organisational architecture as well as IS architecture (Voss and Hsuan 2009).

## 4 Service Strategy & Business Model

There is a four-step approach to developing a successful service strategy: (1) Select the innovation focus, such as new service innovation or service delivery innovation, and the target customer group(s); (2) Uncover customer needs in terms of jobs to get done and outcomes expected; (3) Prioritise customer needs; (4) Develop a service strategy (and attendant service concept) to fulfil the high priority customer needs (Bettencourt 2010). A successful service strategy fits what the customer will value with what the company can deliver. This means aligning the service concept (what it would take to deliver on the customer value propositions), and hence service architecture, with firm's capabilities, resources, culture and strategy.

Experiences of leading companies, such as Southwest Airlines, show that successful strategies would include: (1) close coordination of the marketing and operations relationship; (2) a strategy built around elements of a strategic service vision; (3) an ability to redirect the strategic service inward to focus on vital employee groups; (4) an appraisal of the effects of scale on both efficiency and effectiveness; (5) the substitution of information for other assets; and (6) the exploitation of information to generate new business (Heskett et al. 2008). In addition, six successful strategic practices have been identified for service commercialisation: (1) leveraging fundamental sources of value that influence shareholder wealth, (2) managing customers' perceptions of the service value proposition, (3) creating an attractive financial architecture for customising pricing for profitability, (4) ensuring service excellence in implementation, (5) planning for service recovery, and (6) managing the holistic service experience (including the servicescape) (Bolton et al. 2007). These successful strategic practices mirror the design of corresponding business model design considerations below and require superior collaborative competence. This is because it leverages the firm's dynamic capability to absorb information and knowledge from the environment, customers, and its value networks, and adapt the service to respond to dynamic and complex environments, while ensuring consistent superior customer experience at each service encounter point.

Strategy defines the choice as to which business model among many options to adopt for competition in the marketplace. Thus the chosen business model is a reflection of the service strategy – it represents the logic of the firm, the way it operates and how it creates value for its stakeholders (Casadesus-Masanell and Ricart 2010; Osterwalder and Pigneur 2005). Service business model defines the end-to-end service delivery activities, in accordance with the service concept, by which firms deliver value to customers, entice customers to pay for value, and convert those payments to profit (Osterwalder and Pigneur 2005; Teece 2010). It articulates the logic, the data, and other evidence that support a value proposition for the customer, and a viable structure of revenues and costs for the enterprise delivering that value. Business model embodies the organisational and financial 'architectures' of a business (Osterwalder and Pigneur 2005; Teece 2010). A business model can be conceptualised as a system of interdependent (service delivery) activities that transcends the focal firm and spans its boundaries, and enables the firm, in concert with its partners, to create value and also to appropriate a share of that value. The service business model is composed of two building blocks: (a) design elements – content, structure and governance that describe the architecture of a service delivery activity system (Level 2 and Level 3 of service architecture); (b) design themes – novelty, lock-in, complementarities and efficiency that describe the sources of the service delivery activity system's value creation (Zott and Amit 2010).

In sum, a service firm's customer value proposition crystallised by the service concept serves as the bridge connecting its service strategy and business model. The former defines the service concept and service delivery mechanisms (consistent with the service architecture) while the latter defines the revenue and cost models (financial architecture) of the selected activity system (in accordance with the service delivery architecture) designed to serve the targeted customer segments. Both practices tend to be pursued in parallel and interactively due to their close interrelationship. And both practices are required to create and sustain the competitive advantage for the firm.

## 5 Service Innovation Models and Process

Service innovation is about the creation of customer value (Grawe et al. 2009). The source of service innovation opportunities is from discovering how customers define value – for instance, customers hire products and services or solutions to get a job done; or use outcomes to evaluate success in getting a job done; and have distinct needs that arise related to the "consumption" of a solution (Bettencourt 2010). Four types of service innovation can be identified from the customer viewpoint: (1) New service innovation – discovery of new or related jobs to get done; (2) Core service innovation – helping the customer get a core job done better; (3) Service delivery innovation – improving the ways a core job get done; (4) Supplementary service innovation – helping the customer get jobs done related to product usage or consumption done (Fynes and Lally 2008). Service innovation can also be characterised by the degree of interaction with the customer and the degree of information asymmetry within the service relationship (Gallouj 2002). This section reviews the common, foundational service innovation (functional and competence-based) models and processes for creating all types of innovative services that help customers get their jobs done.

### 5.1 Functional Model of Service Innovation

Service innovation is often a result of a combination of conceptual, technological and organisational innovations combined with new ways of relating to the consumer (Hertog 2002). A commonly used functional model for identifying the focus or vector of a service innovation consists of four dimensions of service: (a) new service concept – a new idea of concept of how to organise a solution to a job/problem in a given market; (b) new client interface – new information-centric (often online) personalised interface (Gallouj 2002) to facilitate service offering co-design, co-production and value co-creation with the clients; (c) new service delivery system and organisation in line with the firm's strategic service vision and new service concept; and (d) technology options – the specific role of technology selected[1] (Gallouj 2002) in the service innovation (Hertog 2002). Thus service innovation is a multi-dimensional phenomenon. A completely new service (radical innovation) usually means innovations in all the above four dimensions. On the other hand, incremental service innovation means innovation in one or more of the above four dimensions. Equally important is the need to address the linkages between these dimensions in order to implement the service innovation, as they represent the requisite marketing, organisational development and learning processes (human resource) (Gallouj 2002; Maglio et al. 2009; Spohrer et al. 2007) and distribution (supply chain/logistics) capabilities to realise the innovation. For example, launching a new service concept requires marketing expertise. The decision as to whether to develop new services requires organisational knowledge: the organisational capabilities required versus available and suitability of existing organisational structure to deliver the service (Gallouj 2002; Hertog 2002). Thus while service innovation may arise from changing one of the above four dimensions, it requires interdisciplinary collaboration between marketing, human resource, distribution and IT to bring about the change and take the innovation to market. In sum, each particular (type of) service innovation is characterised by the combination of the four dimensions: the weight of the individual dimensions and the relative significance of the various linkages between them

[1] Use of technologies in service firms tends to follow the so-called "Barras reverse product cycle RPC" model – start with back-end then front-end process innovations and finally product/service innovation (Gallouj 2002).

(Hertog 2002). To co-create and capture value for the innovative firm, a new business model must be designed that reflects the operating and financial model of the service concept and associated linkages to the other dimensions (Teece 2010).

### 5.2 Competence-based Model of Service Innovation

There are three different approaches to defining and studying service innovation (Gallouj 2002): an assimilation or technologist approach, which treats services as similar to manufacturing; a demarcation or service-oriented approach, which distinguishes services (possessing the aforementioned IHIP characteristics) from manufacturing innovation; and a synthesis or integrative approach, which suggests that service innovation brings to the forefront hitherto neglected elements of innovation that are of relevance for manufacturing as well as services. The synthesis or integrative approach is widely adopted and it is congruent to the service-dominant (S-D) logic. The best known model of this approach is the Gallouj-Weinstein competence-based model (Gallouj and Weinstein 1997) that represents a product or a service as a system of (provider) competences (PCi), technical characteristics (PTi), and final characteristics (Oi), where the service outcome (Oi) is resulted from the interactions between the customer competences (CCi) and the provider's competences (PCi) and technical characteristics (PTi). Service innovations thus consist of changes in one or more of these elements. Provider competences PCi are then the direct mobilisation of service personnel competences (i.e., without any technological mediation). PTi are knowledge, competences embodied in tangible (such as front- and back-office characteristics) or intangible (i.e., codified and formalised competences such as job analysis methods. A fundamental characteristic of service activities is client participation (in various forms) in the production of the service (Gallouj 2002).

### 5.3 Service Innovation Process and Management

Service innovation competence is a crucial operant resource for the firm's competitive advantage. Service innovation practice depends critically on a streamlined and flexible process for internal and external resource coordination and integration to achieve effective and efficient customer value co-creation. Service innovation process, also known as new service development, generally (Engel et al. 2006; Thomke 2003) consists of five phases:

- Create ideas – this phase defines the idea, its scope and business benefits
- Evaluate and select ideas – this phase prioritises the portfolio of ideas and develops the selected idea into a (low cost low risk) experiment to test its feasibility; go/no go decision is made quickly to speed up the chance of identifying a feasible idea (or conversely the rate of failures of infeasible ideas)
- Plan, design, develop and implement ideas – this phase takes the feasible idea through a rigorous service development lifecycle
- Commercialise the ideas – this phase launches the service
- Review the impacts – this phase reviews the results of the innovation to improve current performance and as a feedback for future process improvement

However, as alluded to in the design practices framework (Sect. 3.1), in the digital world this innovation process would not necessarily occur in a purely linear (predictive) manner, rather it would tend to be circularly iterative, akin to "agile (emergent) development".

Research on service innovations has highlighted the critical importance of the front-end stages of new service development: idea generation, idea screening and concept development – collectively known as the fuzzy front-end (Alam 2006). Customer involvements in the front-end stages of a service innovation process are important so as to reduce the fuzziness (Alam 2006). Service innovation may be incremental for steady business growth – through exploitation of existing competences (O'Reilly and Tushman 2008); or radical for new growth idea (Anthony et al. 2008), which could become a new growth platform (Laurie et al. 2006) – through exploration of new competences/capabilities (O'Reilly and Tushman 2008). But the exploratory activities must be buffered from exploitative activities to ensure coexistence (Benner and Tushman 2003), creating a so-called ambidextrous organisation capable of both exploitative and exploratory innovations simultaneously.

Companies are also increasingly leveraging innovative ideas from outside the firms using an open innovation process (Chesbrough 2003). This means the firm needs to engage customers, partners, suppliers, regulators, and even competitors to co-generate creative ideas, co-produce service offerings and co-create value in a continual nonlinear process of service innovation, which supports direct interactions with the customers to match innovations with customers needs (Chesbrough 2011). The aim of customer participation, as described in the next section, is to co-create a "unique personalised customer experience" (Prahalad and Krishnan 2008).

## 6 Customer Participation

Central to discovering service innovation opportunities is "knowing how customers define value" (Bettencourt 2010). As service value is always determined by the customer, new creative ideas must be developed from the customer's outside-in view (Edvardsson et al. 2007; Payne et al. 2008). Indeed, successful firms are co-opting customer involvement in service and value cocreation (Prahalad and Ramaswamy 2000). Customer participation is equally essential to both the 'old' physical and 'new' digital service worlds. However, involving customer in co-production of a service process is often confronted with conflicting design requirements. For example, scale-economy or efficiency requirements would demand service standardisation, while personalised service experience requirements would demand service variability tailored to individual preferences. In general, customer participation is inherently a source of variability since each customer has different capabilities and must learn how to interact with the service process (Metters and Marucheck 2007). The concept of customer efficiency is therefore a critical requirement of service process design to denote the customer's ability to participate in self service or coproduce service (Metters and Marucheck 2007; Xue and Harker 2002) – for instance the user innovation toolkit (Hippel 2001). Similarly, customer variability is, thus, a design variable which can be managed to improve both service quality and efficiency (Metters and Marucheck 2007).

Firms compete through service by collaborating (i.e., co-produce offering and co-create value) with customers and network partners to enhance knowledge (Lusch et al. 2007). This requires the firm to possess absorptive capacity (Zahra and George 2002) in order to absorb new information and knowledge from customers and partners to comprehend from the external environments the important trends and know-how which, in turn, give them the ability to adapt/adjust to the complex, dynamic, and turbulent external environments. Firms that draw on the knowledge of their customer base can capitalise on customer competencies for use during the course of their innovation activities (Blazevic and Lievens 2008).

Customer participation or involvement in service innovation can take place at various phases of the new service development process (Alam 2006; Chesbrough 2011). Customer participation or integration can be conceptualised as the incorporation of resources from customers into the service development processes of a company (Moeller 2008). This would include participating in producing and delivering the service (Dong et al. 2008). Business has to develop an adaptive organisational model where customer involvement and innovation is persistent and inherent in the entire service lifecycle – such that the distinction between customers and employees becomes blurred (Oxton 2008). This organisational model operates as a network of relationships based on the principles of alignment, transparency, identity (reputation) (Oxton 2008).

Customer participation towards creating personalised experience (Prahalad and Krishnan 2008) typically follows a five-stage iterative approach: 1) establishment of antecedent conditions for customer to participate; 2) development of motivations or customer benefits; 3) cost-benefit evaluation; 4) activation of co-creation process by choosing the stages of the "production-consumption" activity chain; and 5) evaluation of the effectiveness of the co-creation strategies against the cost-benefit analysis (Etgar 2008). It is prudent for the provider to institute a continuous learning process with the customer from the co-creation experience to improve their service-usage competence. Learning enhances the customer's competence in seamlessly integrating the value proposition with their lives, objectives and aspiration (Payne et al. 2008). Organisational learning about customer's value creation processes deepens customer insights. Organisational learning is a crucial process for nurturing the provider's collaborative competence to improve the provider's innovation capability and competitive advantage (Edmondson 2008).

The increased digitalisation of services in the internet era is creating new opportunities for knowledge coproduction between customers and the provider (Blazevic and Lievens 2008). In a digital world, customers may take on three different roles for knowledge coproduction-passive user, active informer, and bidirectional creator-each with distinctive declarative and procedural characteristics, and distinct impacts on the three innovation tasks of detection, development, and deployment (Blazevic and Lievens 2008). The digital world also facilitates customer participation in recovery from service failure. This may vary in degrees from firm recovery, joint recovery, to customer recovery (Dong et al. 2008). This would require higher levels of role clarity, but it also tends to enhance satisfaction with the service experience, perceived value in future co-creation, and intention to co-create in the future (Dong et al. 2008).

## 7 Community-based Innovation

The advent of social media and clouds-based services has led many firms globally, as part of implementing their social strategies, to directly engage with their customers online across a broad range of activities (such as marketing, customer care, etc.) to co-create value for mutual benefits. This has evolved from a relatively straightforward traditional online customer service platform to a more sophisticated community based innovation (CBI) which requires a new set of organisational capabilities that interact and integrate with those of the customers themselves (Fuller et al. 2006).

CBI is defined as a new online service innovation process that fully engages the firm's customer community from ideation phase right through to the test and launch phase of New Service Development. The community members become the sources of new service ideas as well as the co-creators and evaluators of the service designs. The most common CBI user/customer archetype is called the "lead users" – who are highly knowledgeable of the firm's products/service and have 'job' (problem) needs that are ahead of all other user groups in a given market. Lead users are allowed to design (using interactive toolkits provided by the service provider) their own products/service by trial-and-error according to their wants and needs. Their creativity and problem-solving skills (competencies) using the toolkits (provider competencies) will produce the 'ideal' solutions to match their problems (the 'jobs' to be done) – for instance, Peugeot's "Retrofuturism" car designs were produced using CBI[1] (Fuller et al. 2006). Two other user archetypes are also common: the "insiders" who are strongly associated in the community and highly involved in the topic; the "devotee" who are highly involved with

[1] www.peugeot-avenue.com.

the topic but not very much related with the community. CBI communities could be selected on the basis of the exchanged content, professionalism, traffic volume, and number of participants interacting with each other (Fuller et al. 2006). Users could be accessed directly or more often they recommend access via a trustworthy member of the community or via the webmaster to increase acceptance. Feedback to users on their input is regarded critical as is getting users' feedback on their participation experience and their willingness and expectations to participate again in future virtual product/service development projects (Fuller et al. 2006).

Community members engagement in CBI can be fostered and sustained in a three-step process: (1) understand consumer needs and motivations; (2) promote community participation, including encourage content creation, cultivate connections, and create enjoyable experiences; and (3) motivate cooperation, including mobilising member-leaders, inspiring idea creation and selection via a panel/polling (Porter et al. 2011). Community engagement is motivated intrinsically by the value created when community sponsors help user-members meet their needs with their virtual community. So the community sponsor's judicious and targeted efforts to encourage members to act in ways that create greater value for themselves and for the firm are crucial to success (Porter et al. 2011). Members' "embeddedness" (willingness to act in value-creating ways toward a community sponsor) and "empowerment" are seen to be fundamental to driving cooperative, engaging behaviour from the community members (Porter et al. 2011). This, in turn, would require the community sponsor to understand the needs of its community members, build trust with and create value for its members (Porter et al. 2011). CBI tends to focus on firm-community (one-to-many and many-to-one) collaboration. More recently, new social strategies are being proposed that seek to reduce company costs and/or increase customer willingness to pay by helping the community to meet online and strengthening their relationships – that is focus on many-to-many social activities between community members as exemplified by eBay's Group Gift (Piskorski 2011).

## 8 Strategic Management for Innovation Success

Innovative service firms have strong commitment to innovation from top management backed by well structured innovation processes and governance together with the aligned culture and systems, and the attendant prioritised resources allocated to innovation efforts. In service innovation "it is not the service itself that is produced but the pre-requisites for the service" (Edvardsson and Olsson 1996). Due to services' real-time production, new service development would require modifications of the service delivery process and changes in frontline employees' skills. This would require strong fit between the new service and existing systems; and close alignment between the customer-service-focused front-end and the operational-excellence-focused back-end systems.

But despite its strategic importance, service innovation is notoriously difficult to accomplish (Dorner et al. 2011). This could be attributed to such managerial deficiencies as: lack of ability to protect services hinders investment; lack of clear "organisational anchoring" of service innovation activities; lack of systematic innovation process; lack of customer participation; and "bad ideas not consistently eliminated" (Chandy and Tellis 1998). So managers need to be vigilant in all innovation stages to assess ideas against the company's strategic goals and market needs in order to determine their commercial viability. Further, managers need to focus on people (evolving competences in line with changing customer value expectations) and structural support (systematic new service development process supported by specific innovation tools, multi-disciplinary teams, the availability of resources, market testing and market research) to ensure successful service innovation (Dorner et al. 2011).

Service innovation is technology-enabled but more human-centred and process-oriented. Therefore, the "envisioning, energising and enabling" capabilities, sound communication/co-ordination, and reducing intra-organisational conflicts and power struggle have been identified as fundamental and very critical for new service development to minimise organisational inertia/resistance (Nijssen et al. 2006). Innovative firms commonly possess "willingness to cannibalise" mindset and capability – i.e., willingness to make obsolete its existing products/services, prior investments, and/or existing organisational capabilities (Chandy and Tellis 1998; Nijssen et al. 2006). These innovative organisations are said to possess ambidexterity capable of pursuing simultaneous exploitative and exploratory innovations. An ambidextrous organisation "requires a coherent alignment of competencies, structures and cultures to engage in exploration, a contrasting congruent alignment focused on exploitation, and a senior leadership team with the cognitive and behavioural flexibility to establish and nurture both" (O'Reilly and Tushman 2008).

## 9 Conclusion

Service innovation is focused on creating customer value, and service is about relationship with the customer. Customer co-creates value with the provider by integrating his/her competences/capabilities with those of the provider. Thus customer productivity is as important as that of the provider in service provision as it impacts directly the service experience. Increasingly, in a digital world, customer and member-community participation across the firm's entire service innovation lifecycle is becoming a critical innovation strategy for sustained value co-creation. It has become a core and distinctive organisational capability for service organisations to develop and adapt in line with the evolving external environments and the customers' increasingly mature service competences.

Service innovation is technology-enabled but more human-centred and process-oriented. This is accentuated by the design practices framework for service innovation which serves as a foundation for systematic service conceptualisation, design, architecture and innovation. Service innovation commercialisation is contingent on mindful alignment of the firm's service strategy, service concept and business model. Firm needs collaborative, absorptive capacity and dynamic capabilities (including organisational learning processes) to continuously adapt its service innovations with the changing external environments including the value networks to which it is connected. From strategic management perspective, the firm needs to be ambidextrous capable of pursuing exploitative and exploratory service innovations simultaneously to create sustained value for itself and its customers.

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# Big Data Management and Analysis for Business Informatics

## A Survey

*Modern communication networks have fueled the creation of massive volumes of data that may be valued as relevant information for business activities. In this paper, we review technologies for enabling and empowering business activities, leveraging the content of this big data. We distinguish between data- and user-related technologies, and study the parallel brought by the overlap of these categories. We show how the trend of Big Data is related to data security and user privacy. We then investigate automated ways of performing data analysis for Business Intelligence. We finally review how groups of users may be seen as a workforce in business through the notion of human computation or crowdsourcing, associated with the notions of trust and reputation. We conclude by discussing emerging trends in the domain.*

## 1 Introduction

Progress in *Business Informatics* aim to develop business administration using computational and information technologies. As such, business informatics may use any method providing a technology useful for its end purpose.

Modern business activities essentially rely on an accurate management of knowledge (often referred to as *Business Intelligence*). The development of communication technologies and the wide-spread and ubiquity of communication networks have created an opportunity for gathering and analysing data in view of deriving useful knowledge. Hence, business informatics is primarily supported by data management and data analysis technologies. In addition, users and user groups remain at the center of any business. They may assist performing data analysis as much as benefiting from it.

In this paper, we review and analyse the main enabling technologies in business informatics. We explore as thoroughly as possible the information landscape in which business informatics operates, to understand the aspects and their characteristics, potential risks and benefits. User-generated data is considered a potentially rich source of information for business and user behaviors are modeled using this data. Users and data are therefore two inter-related main *actors* within this landscape that we explore via these two perspectives, as illustrated in Fig. 1.

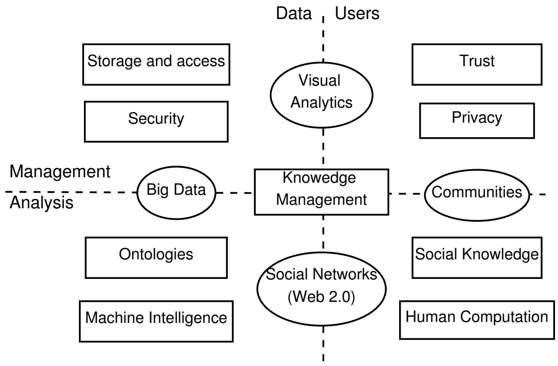


*Figure 1: A classification of domains for enabling and empowering technologies in business informatics. Square boxes indicate technical domains, whereas circular items relate to multi-disciplinary binding fields of study*

Investigating data-related aspects allows to understand the technical infrastructure that should be set up and sustained, from base data collection and housing to sophisticated data analysis. In parallel, studying user-related issues allows to model the user and his community, as originator of this data. We therefore distinguish between data- and user-related technologies, although the split is somewhat artificial since these technologies generally overlap. We further look into passive *management* technologies (whose main aim is not to create any knowledge) against active *analysis* technologies (that transform data into knowledge). The extend of our review is symbolised in Fig. 1. Section 2 reviews the housing and preservation of data, in relation to the current challenge of *Big Data*. In Sect. 3, we review automated technologies for data analysis. These are crucial for their aspect of scalability, since any necessity for user intervention would create prohibitive costs at large scale. As a mirror to the data-related sections, Sect. 4 reviews user-related strategies, from preserving user privacy to exploiting the force and intelligence of the crowd. We discuss the future potential of reviewed technologies and foreseeable extensions in Sect. 5.

## 2 Data management

While information and communication networks have triggered the creation of an overwhelming mass of data, they have also created opportunities to monitor and mine this data, thus augmenting drastically the volume of contextual information potentially available. Massive collections of digital documents are made available, either publicly on the Web or in private networks related to companies, workgroups or social associations. Data may be very diverse and arise from any form of information exchange. Examples of this include:

- Textual: Web pages (personal, professional, from individuals, groups or companies), emails, blogs posts, news feeds, exchanges over social networks;
- Multimedia: photos, videos, music, audiovisual blogs, ...;
- Process data: sensing data (GPS, weather, traffic monitoring, ...), computation (sociological, scientific, financial trends, ...);
- Logs: traces of human interaction with systems (information, e-commerce, entertainment, ...), logs of machine-machine communications (web services, distributed computing, ...).

Before considering data analysis, a choice is to be made on the form of data housing, if any. The emergent paradigm of big data (Sect. 2.1) is addressing some choices there. In turn, data preservation and access immediately open security issues, reviewed in Sect. 2.2.

### 2.1 Big data

Every study on the topic shows clearly that the volume of data created by individuals and companies is growing exponentially (see, e.g., Manyika et al. 2011). In parallel, analysts predict success to anyone who will exploit this data accurately, thus implicitly supporting the meaningfulness of this data. However, this data is everything unlike what companies are used to deal with. It is unstructured and redundant and potentially noisy or corrupted. Every piece of the data may be seen as noise that would pollute a database of clean and structured data. There is nevertheless a clear intuition that the mass compensates for the defects of the pieces. A global picture of the data should contain information that could be exploited to many ends. This is the challenge of the recent trend identified as *big data* (Big Data: Science in the Petabyte Era 2008; ERCIM News Special Theme: Big Data 2012).

Big data has initially been characterised by its "three Vs" (Fayyad 2012), mostly addressing its technical specificity:

- **V***olume*: In itself, the volume of this data is an issue. It surpasses many of the simple storage strategies classically used. At this scale and evolution rate, it is hardly possible to structure and clean the data, for both technical and cost reasons;

- **V***ariety*: In order to transform data into knowledge, its multiple facets should be taken into account (see Sect. 3). The data in question therefore encompasses a high diversity in its content, format, structure and interpretation. Again, this goes against most principles of classical data management and storage paradigms where the structure of the data should be understood and stable;
- **V***elocity*: One of the main characteristics of big data is the pace at which it is generated and at which it evolves and gets obsolete. In other words, this data inherently bears a strong temporal dimension. Usage logs, trends, news, are all content that have a strong interest in their immediate history and quickly decline into useless or even polluting data. However, this data may also have a behavioral interest at long-term on a more global temporal scale (e.g., Morrison et al. 2012).

These technical factors prevent the use of the typical database models (e.g., a relational structure made usable via SQL) and impose to move onto more flexible, agile and scalable structures (including the *NoSQL* trend[1] advocating for schema-free storage or the MapReduce model (Dean and Ghemawat 2004; Mohamed and Marchand-Maillet 2012)[2] to support indexing, e.g., via the agnostic name-value pair model). Decentralised storage and processing systems (a.k.a Peer-to-Peer systems or *the Cloud*) rely on structures having these characteristics to make the data safe, ubiquitous, and accessible ("Anything, Anywhere, Anytime").

In practice, the current appeal for big data has mapped into new functions coined as *data scientists*, i.e, data analysts able not only to perform technical operations on the data such as preparation, cleaning, compaction, *etc*, but also to contextualise the data and read it with all surrounding parameters (e.g., social context, as detailed in Sect. 4.3).

[1]Web-scale databases: http://nosql-database.org
[2]The Apache Hadoop library: http://hadoop.apache.org/

Many "Vs" have been added to big data (e.g., Viability, Veracity (Vossen 2013), Volatility, ...) but the main "V" business is concerned with is

- **V***alue*: The question is "how to make value out of this large, complex and unstable stream of data?"

There are many answers to that question, including:

- By better understanding actions and behavior of its customers, traced by the log of their actions, a company will be able to offer better and more relevant services;
- By better understanding the context within which it operates, characterised by the mining of environmental factors, a company will lower its risks.

The first common step is always to transform data into knowledge, partly thanks to the technologies reviewed in the next sections. One finds reports on success stories of big data analytics[3] relating how such insurance company could fine-tune its risk model using deep data analysis, including exploiting inferred customer social relationships (which in turn poses questions on privacy - see Sect. 4.1. Looking at business as a permanent complex constrained optimisation problem, where the right balance should be found ("price *vs* volume, cost of inventory *vs* the chance of a stock-outrisk"[3], *etc*), the success of big data is in providing insights into how to rationalise decisions on these tradeoffs. In that case, the *noise* in the data refers to any potential inconsistency in data patterns, unintentional (e.g., failures in process or communication), or intentional (e.g., spam (Mukherjee et al. 2012)).

It should be emphasised there that as much as there may be some benefit for a company to extract knowledge from the data, there is an inherent risk that this data is used by an adversarial party in many ways. These includes industrial

[3]e.g., http://www.forbes.com/sites/mckinsey/2012/12/03/big-data-advanced-analytics-success-stories-from-the-front-lines

espionage for adversarial reasons and unfair competition, signals intelligence collection and analysis[4] for (state) security reasons and customer privacy breach or exposure[5], either intended or accidental. This then forces to ensuring the security of the data and the privacy of the user, which we study next.

## 2.2 Data security

Securing data first aims at preserving its *integrity* and *confidentiality*, while not imposing constraints on its *availability* to authorised parties. Issues linked to its *authenticity* and *accountability* are related to its integrity, while data access is characterised by *non-repudiation* and *reliability*.

Data security is related to data usage and there, related services include *user authentication*, *user authorisation*, *access accountability* and *user reliability*. This finally mirrors to user privacy and trust, studied in detail in Sect. 4.1 and Sect. 4.2, respectively. The relationship between data security and user privacy is established via “guaranteeing privacy by securing access to private data”. On a sociological level, the *Security Culture* (Alnatheer et al. 2012) is defined as the level of belief and expectations members of a group (e.g., an organisation or company) have regarding security. This is valid at all levels of the organisation and, in Ruighaver et al. (2007), it is demonstrated that the effectiveness of operational security policies in an organisation is positively correlated with the belief that the top management (decision makers) have in these policies. Greene and D’Arcy (2010) verify empirically the hypothesis that security culture (i.e., beliefs) and job satisfaction lead to a increased security behavior in the organisation.

A further distinction regarding the integration of data security is to be made between the public and private sector. The absence of economic markets for final product outputs in the public sector and the associated reliance on government financial resources place public agencies under strong political influence. As a result, information management systems in public organisations emphasise more the environmental factors rather than internal characteristics from the organisation. As demonstrated in Conklin (2007); Wang (2009), these differences play an important role in the diffusion of technology in e-government settings. In particular, decisions made on information security management in public organisations do not always follow technological rationales (Ruighaver et al. 2007).

Technologically, the challenge is to define security strategies in the *Information Management System* that will support business processes (see, e.g., Diesburg and Wang 2010 for technical surveys on digital data security). As given in Place and Hyslop (1982), Information management focuses on “plans and activities that need to be performed to control an organisation’s records”. Here, security should “ensure the continuity and minimise business damage by preventing and minimising the impact of security incidents” (Solms 2006, 2010). Authors of the latter references structure the evolution of security policies into several waves (illustrated in Fig. 2) showing the focus of every development phase, from purely technological to management-related concerns.

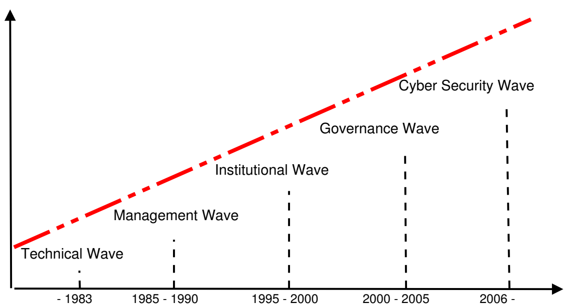


*Figure 2: The 5 waves of Information Security (created after Solms 2010). The drift from technical to societal issues is clearly visible*

From its origins (first wave), information security has been seen from a technical perspective. With

[4] e.g., the Echelon Network (2001) over communication networks, or the Prism Initiative (2013) over the Web

[5] e.g., the case of “AOL user 927” (2006)

the stability of the technical solutions, the question has moved onto the integration of security practices at a management (second wave), institutional (third wave) and governance (fourth wave) levels. The interweaving of private and public communication networks (e.g., private companies exposing themselves on the Web) has generated the related security issues of cybersecurity (fifth wave). Here, the construction of a secure context over highly complex interconnected communication networks (cybersecurity ERCIM News Special Theme: Cybercrime and Privacy Issues 2012) should go with the help of reference organisations such as the ISO/IEC (COBIT (Control Objectives for Information and related Technology) 4.1: Framework for IT Governance and Control Last retrieved: June 2013; ISO/IEC 27002:2005. Information technology – Security techniques – Code of practice for information security management 2005). These institutions supervise the creation of standards whose role is to protect an organisation's information asset in the context of confidentiality integrity and availability. Standards are generally largely biased, depending on economical, political or simply technical interests. In every domain, the debate of which standard is better always exists. Data security is no exception (see, e.g., Solms 2005). In the particular case of big data, valuable information is potentially hidden within massive amounts of data. Hence, in this context, defining the cost-benefit tradeoff of securing data is a hard task. As much as there are open technical challenges for securing data at very large-scale, there are also strategic open questions on the overall gain of such efforts. In the context of business informatics, the data often originates from customer behavior or input. Security questions therefore go beyond the technical benefits (e.g., the quality of data modelling), they encompass ethical issues, related to user rights issues related to data preservation (e.g., including privacy, as detailed in Sect. 4.1)

## 3 Data Intelligence

Business intelligence is related to an accurate use of the data collected at large scale. The main aspects of this adequate management is the accessibility and legibility of knowledge where available, and the creation of knowledge by automated or supervised processes. Figure 3 schematises the stages for the creation of knowledge from data, leading to accurate decision-making support.

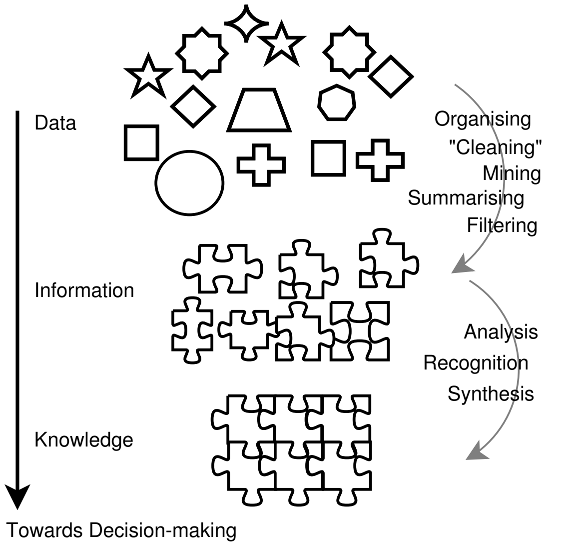


*Figure 3: Creating knowledge from data*

Data is the raw material that can be collected, either as characteristics (of users, products, *etc*) or as traces of activities (logs, sensing, results, *etc*). Information is obtained by compacting data into its coherent structures (e.g., patterns, summary). This step consists in aligning the data onto a model. Knowledge is obtained via processing Information with a high-level of understanding (e.g., semantic understanding). This step consists in matching the Information with known high-level concepts.

### 3.1 Knowledge Management

The domain of knowledge management, via the definition of extensive data description schemes offers solutions for accurate (semantic) query-based information or service access. The grail of *Knowledge Management Systems* (KMS) is reasoning and inference. From a non-redundant, but complete, knowledge representation, data content or actor behaviour may be predicted and linked together. However, the complexity and induced costs of design, creation, maintenance and compatibility of such descriptions generally impede their usage and development at large.

These strategies nevertheless find applications in well-understood, closed domains. Hence, besides their utility in representing knowledge via ontologies and inference models aligned with the semantic web, KMS (Abramowicz et al. 2010; Hu et al. 2010; Jiang et al. 2009) have been applied to specialised domains, including domains related to business. This is the case for enterprise modelling (Frank 2013) and cartography (Tribolet and Sousa 2013) and the modelling of business processes (Abramowicz et al. 2009; Sanz 2013). The reader is referred to the latter references for further insights in future developments of knowledge management in all aspects of business modelling.

### 3.2 Data mining and filtering

*Data mining* is the unsupervised (or weakly supervised, where weak assumption may be made over the inner structure of the data at hand) discovery of recurrent or coherent patterns in the data (Fayyad et al. 1996; Rajaraman and Ullman 2012). It develops in parallel to the field of *Machine Learning* (see, e.g., Domingos 2012) where the aim of the supervised process is to teach the machine specific decisions via the processing of examples. As such, data mining maybe coined as *Knowledge Discovery* (finding recurrent patterns in the data), complementing knowledge management, whereas machine learning is about *knowledge propagation* (extending known decisions to unknown situations), related to the field of *Predictive Analysis*. The flow of information evolves with time and trends develop. Such trends are characterised by the emergent surges of information patterns such as recurring keywords or phrases within text, or repeating events in usage logs. A particular case of data mining, suited to business informatics, is therefore *Emerging Trend Detection* (ETD) (Kontostathis et al. 2003). It studies flows of information along a timeline and extracts specific topic areas whose focus becomes more important at a point of time. It should be viewed as an automated mining process, since the manual inspection of flows of information at large-scale is simply not feasible. ETD is of crucial importance for data analysis, event prediction and decision-making in many areas, including business, finance, or politics. As such it is fully relevant for the analysis of big data. By identifying growing interests, actors of these domains will be able to react accordingly and even predict future evolution. For example, based on mining discussions over a social network, a company may decide to create a new product associated with a trendy product (e.g., sensitive pens for tablets) or, on the contrary, retract a product whose philosophy goes against current trends (e.g., large cars go against emerging "green" feeling). Investors may also anticipate fruitful niches if they can detect emerging trends at an early stage. They may also learn from the past by mining historical data to understand what caused the success or failure of such investment or product.

ETD generally considers documents as being aligned along a timeline and emerging trends also appearing and growing along that timeline (Ganesh et al. 2011). An early survey in (Kontostathis et al. 2003) lists and analyses systems proposed in the late 90's that operate on textual technical data such as the INSPEC database and the IBM DB2 US Patent database. In Le et al. (2005), a technique also applying on the scientific literature is proposed to track trendy topics using counts and bibliographic measures along time. Several temporal models have been proposed for the analysis of topics over time such as the *Dynamic Topic Model* (Blei and Lafferty 2006), *Topics* *over Time* (Wang and McCallum 2006) and the *Trend Analysis Model* (Kawamae 2011).

The medical literature, notably with the availability of the PubMed database is a domain of interest for ETD (Mörchen et al. 2008). Goorha and Ungar (2010) apply it to news wire articles, blogs posts, review sites and tweets, in search for interest rises in products or companies. A huge flow of information is processed daily based on word and phrases counts. Leskovec et al. (2009) correlate the appearance of given phrases in news with its occurrence in blogs. Similar studies have more recently be applied on Twitter data (e.g., Weng et al. 2010).

Collaborative and hybrid *recommender systems* (Park et al. 2012) leverage the wisdom of the crowd and propagate user interests across a community. They can result in the emergence or fall of an item, an idea by aggregating and propagating adequately consistent user judgements. Collaborative filtering operations may be seen as a local form of mining and trend detection within user interests. As such, they are also very close to the notion of crowdsourcing (see below). The main idea is to create a bipartite graph between products and customers where user ratings (judgments) are used as edge weights. Information is then propagated along this graph to group customers and/or products and thus, predict new edge weights (i.e., the judgement of a costumer over a product).

This framework for recommendation is used in Selke and Balke (2011) to cater for the lack of relevant or accurate information available to customers over "experience products". Authors demonstrate the effectiveness of their technique in the context of movie recommendations. This relates the idea of creating online and automatically item descriptions and therefore also relates to information retrieval. An early study on how such systems may be formally evaluated is proposed in Herlocker et al. (2004).

Whereas collaborative filtering uses implicit or explicit user judgements, sentiment analysis (a.k.a opinion mining explores blog texts, customer reviews or comments to track the acceptance or rejection of a product, an idea or a decision within a population (customers, voters, *etc*). Several approaches exist, including using *sentiment dictionaries* to map text words to opinions or sentiments with polarity (is/is not) (Liu 2012).

### 3.3 Information access: retrieval, filtering and browsing

Search and retrieval operations have installed themselves as a base paradigm for accessing items from within a repository. They are mostly based on the notion of a query formulation (Baeza-Yates and Ribeiro-Neto 2011). (Seidel et al. 2008), for example, demonstrates how such tools may support creativity in a business context.

Since precise data description is often a costly operation (or simply incompatible with the pace at which data is produced), in the case of systems operating over poorly described or non-textual data, the idea of *query-by-example* has emerged (Rui et al. 1998) as a help to construct accurate queries. Positive and negative examples are aggregated over intermediate search operations, in order to form a descriptive set for the sought items. Examples then become the base for online learning operations, so as to generalise *classes* of provided *relevant* and non-relevant items (Bruno et al. 2007; Wyl et al. 2011).

Browsing systems have been proposed and are also mostly based on the definition of a search objective (Heesch 2008). Such systems are typically oriented towards the localisation of a known information, be it media copy detection or user's *mental model* localisation (Ferecatu and Geman 2009) (see also Fig. 4). They iterate user *judgements* over appropriately-chosen sample sets of information to estimate the target item the user has in mind. This framework has been extended by (Lofi et al. 2010) from photo search to product browsing for mobile e-commerce.

*Adaptive Hypermedia* (AH) also relies on the navigation paradigm for information exploration to resolve the issue of complex query formulation. As accurately given in De Bra et al. (2004):

> "The core problem in finding the information you want, in all the above cases, is *describing* what you want. Results from search engines are often disappointing because most search requests are too short and unspecific to yield good results. Once a Web site with interesting information is found, it is often difficult to navigate to interesting pages only, because the site can only be navigated using its predefined link structure, independently of the search request that brought you to that site. The community of *user modelling* and *adaptive hypermedia* offers solutions for this problem: using information gathered about the user during the browsing process to change the *information content* and *link structure* on-the-fly. User modelling captures the mental state of the user, and thus allows that knowledge to be combined with the explicit queries (or links) in order to determine precisely what the user is looking for. To support the design of this user model-based adaptation, reference models like AHAM (De Bra et al. 1999; Wu 2002) and Munich (Koch and Wirsing 2002), both based on the Dexter Model by Halasz and Schwartz (1994), have been introduced in an attempt to standardise and unify the design of adaptive hypermedia applications, used mostly in isolated information spaces such as an online course, an electronic shopping site, an online museum, *etc*".

In Brusilovsky (2001), a taxonomy of AH technologies is further presented. The taxonomy is analysed in detail in Stash (2007), along with an extensive review of AH systems.

The above involves the notion of *user modelling* and a comprehensive review on personalisation research in e-commerce is presented in Adolphs and Winkelmann (2010).

*Information filtering* comes as a helper solution for the interactive formulation of search queries. Rules are defined over product characteristics, in order to define the class of the sought items as the intersection of solution sets for the rules. Rules are generally based on information *facets*. Facets are orthogonal, mutually exclusive dimensions of the data whose range is quantised in relevant intervals (Hearst 2008). Facets may be determined from the data model itself by highlighting important characteristics of the data. In exploratory conditions however, i.e., when the data is not fully understood, it may be interesting to let facets emerge automatically or interactively for providing interpretation of its organisation and to facilitate its exploration (Zwol and Sigurbjörnsson 2010). Several routes may be taken to automatically determine data facets. They all consist in using the data or a representative sample in a mining process to identify a reduced set of orthogonal projection operators whereby every data item is identified by its set of projections.

Faceted search is extensively used over e-commerce sites when products bear inherent orthogonal characteristics. For example, this is the case for real estate commerce with facets such as product type, surface, region, price range, ...

### 3.4 Visual analytics

The above tools are used to make sense of the data itself, using the intrinsic data content or the usage context of the data. *Visual analytics* refers to "the science of analytical reasoning facilitated by interactive visual interfaces" (Heer and Schneidermann 2012; Keim et al. 2010; Thomas and Cook 2006) and creates a link between content-based data mining and interactive data exploration techniques, as described above.

Visual Analytics supports the user in exploring the data and to interactively guide the system to find a formal solution that matches an intuitive solution (the mental model) to the problem (see Fig. 4).

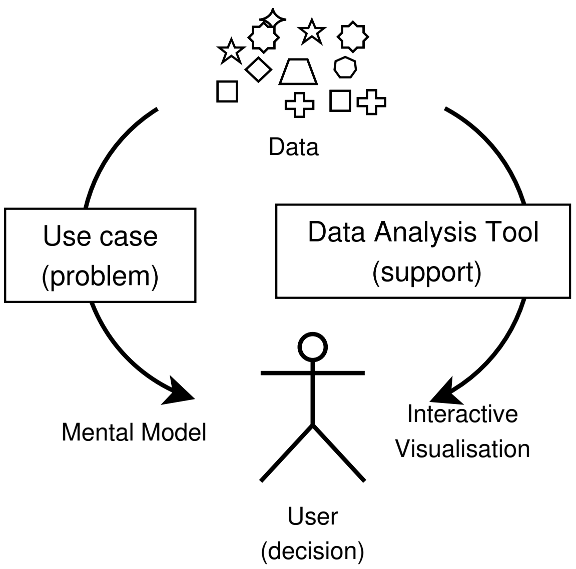


*Figure 4: The process of Visual Analytics where the user is matching a mental model of the solution with the knowledge inferred from the data (see also Fig. 3)*

In Zhang et al. (2012), a review of commercial systems for Visual Analytics, to support facing this big data era is proposed in the context of Business Intelligence. Various use cases are explored (inc. medical, microblogging) and performance over factors such as scalability and effectiveness for supporting decision-making are given. Authors then issue a number of future challenges related to effective large-scale data analysis.

One of the key parameters in interactive data analysis is to offer proper user interfaces and to adequately leverage the potential of user interaction, seen as a source of semantic knowledge into the system (Morrison et al. 2012). The role of users and user groups is studied in the next sections.

## 4 From the user to the community

While an accurate use of the data is fundamental to the decision process, the ultimate actor in the process remains the *user*. There are many user-related issues technologies should take care of. As much as data should be secured, the privacy of a user should be guaranteed. This will allow the user to act freely in the environment s-he is confronted with. Consequently, a consistent and reliable user behaviour may lead to trust and high reputation that may be used in many contexts for information access and recommendation.

Thanks to ever-developing communication media, users may also group into communities and form social groups. The emergence and identification of such social networks allows the analysis to move from the individual to the prototypical user-community s-he belongs to. This electronic crowd represents a task-force and a mass of semantic knowledge that crowdsourcing efforts aim at capturing.

### 4.1 User privacy

User privacy (Danezis and Gürses 2010; ERCIM News Special Theme: Cybercrime and Privacy Issues 2012; Hansen et al. 2008) is directly related to data security. The relationship between data security and user privacy is established via “guaranteeing privacy by securing access to private data”.

User privacy can be understood as a two-fold concept, ethical and technological. Ethics should prevent the usage of user data to infer specific user needs and thus make that user fragile over communication networks. User data should be studied statistically and anonymously so that it returns to the user as a member of one user class, not as an individual. Many more ethical aspects should be defined in parallel of the advent of big data (Davis 2012). This is the role of governmental or not-for-profit independent organisations (e.g., the UN World Trade Organisation) to counter the temptation of inadequate usage of this data from large Internet companies, even though it is known that individuals value their privacy but tend to give it up easily as customers (Pogue 2011).

Technological solutions should ensure that the user data and behavior (e.g., mirrored into usage logs) remain private and are not accessible in their raw form to anyone. Anonymity may be a solution to privacy (Edman and Yener 2009), but again, this approach may not be feasible anymore, as soon as the individual becomes a customer or a user of social networks (De Cristofaro et al. 2012; Fung et al. 2010).

Also related to privacy is the possibility for secure authentication (Poller et al. 2012), preventing identity spoofing. These fields, associated to digital forensic and secured biometrics, directly relate to the notion of trust over communication networks.

### 4.2 Modelling trust

Trust is a social notion that an individual or a group (persons or organisation) develops over time and along experience. It measures the belief that the actions of an individual or a group may be predicted (e.g., from social knowledge of the individual or group) and stay within the limits of a predefined frame. Trust is closely related to the notion of reputation (Castelfranchi and Falcone 1998; Pinyol and Sabater-Mir 2013). It is opposed to the adverse behaviour of cheating via fraud and attacks (Hoffman et al. 2009). As such, the estimation of trust and reputation represents the estimation of a risk for the environment where the individual or group in question is active.

Models for trust and reputation over communication networks such as the Internet have been proposed with essentially two approaches. The *game theory approach* formalises a competition context where the objective is to maximise payoff with minimising risks. Trust estimation therefore relies on associated risk-minimisation tools. The *cognitive approach* accounts for elements such as beliefs, goals, desires and intentions. As such the resulting trust models bear as much value in their result than in their capability to explain the result. A thorough review of these models and their classification is proposed in Pinyol and Sabater-Mir (2013). These models are important to estimate the value of user interaction in systems such as recommender systems (Maida et al. 2012) (see also Sect. 3.3 above).

### 4.3 Social Network analysis

The constitution of social communities and groups of interest have allowed to move from the individual perspective to mass-address for business (essentially for push-based advertisement, the main revenue model for the Web). The study of social networks is therefore essential to structure the potential of such communities, including via the detection of key network features such as connectivity and influential nodes (Gomez-Rodriguez et al. 2012; Sun et al. 2013).

In relation to adaptive hypermedia and recommendation systems, where it is the study of user interaction that leads to recommendation, the study of social media (media hyperlinked in social networks) may allow the inference of recommendation (friends over Facebook or connections over LinkedIn) (Backstrom and Leskovec 2011). One of the difficulties here is the scale at which algorithms should operate. A compensating advantage of human-structured networks is their reputed low diameter (originally valued to 6 (Schnettler 2009), but said to be reduced to 4 over social networks) enabling local computations.

### 4.4 Social labor: Human Computation and crowdsourcing

There is a large labor potential to leverage over the Internet. This is known as *Human Computation* (Ahn 2005; Quinn and Bederson 2011) and also relates to crowdsourcing (Jones 2013). This strategy is, for example, used to help digitising characters via the ReCAPTCHA (Completely Automated Public Turing Test To Tell Computers and Humans Apart) system. Here, the trust in the user is evaluated by presenting a problem with a known answer. The answer to an unknown problem proposed simultaneously is then used as a statistical clue towards the right solution of this latter problem. In general, these tools, along with the *Games With a Purpose* (GWAP[6]), use the fact that human capabilities to perform (visual) pattern recognition surpass

[6]Games With a Purpose: http://www.gwap.com

by far that of an automated process, with the incentive of fun or commercial advantage. Recommender systems may also be seen as a form of crowdsourcing in that they seamlessly federate user judgements to create semantic information about items, products or services.

The impressive performance of such collaborative systems demonstrate the potential of labor to be federated over the internet. Another way of federating the crowd as a workforce is the use of digital labor (Larson et al. 2012). For example, the Amazon Mechanical Turk mediates between job requesters and workers. A requester creates a HIT (Human Intelligence Task) and proposes a reward for it. This HIT generally consists of a short but repetitive task such as asserting the presence of an object in an image. The trust into workers' competences may be evaluated by initial trials and a reputation system is active for both workers and requesters.

Eventually, if enough workers act on a simple task, this workforce constitutes a parallel processing machine (e.g., the *click-farms* to cheat Internet ads) and software APIs have even been developed to make that process fully transparent.

### 4.5 Social knowledge : Folksonomies

While human labor may be organised over the Internet, there are also several initiatives to federate human knowledge, following the "Wisdom of the Crowd" paradigm (Surowiecki 2004). Beyond the ever-growing Wikipedia and its collaborative edition model, including trust and reputation mechanisms, the combination of the semantic web and Web 2.0 for social behaviour enables the gathering of a social knowledge, known as *folksonomy* (Lohmann and Díaz 2012). This knowledge is made accessible accessible to machines via semantic web technologies and also offers a great potential for the development of adaptive or human-tailored business services.

## 5 Discussion and conclusion

Modern communication networks have fueled the creation of massive volumes of data. In this paper, we have discussed how this data may become an asset for business activities. This thorough overview of the information landscape, augmented with a large number of key references aims at providing a faithful picture and guideline for the practitioner who wants to attack the problem of data management and analysis in a business context. We highlighted and exemplified the potential benefits of data analysis but also the complexity and issues related to this task. We advocated for considering in parallel the data and the user viewpoints. Both perspectives share commonalities in their structure and analysis. The first being that most of the data originates from the users and that the users will then be modeled (in their behavior) via the analysis of data. Further, as much as data may be seen at different scales, user and user communities may be modeled at different scales. There is therefore much to gain in keeping this relationship alive when exploring and exploiting the data.

In this era of big data, large-scale data analysis becomes a strategic field of development. The promise of a *reasoning machine* by the field of artificial intelligence in the 1960's has been replaced by the statistical crunching of massive data with the side effect of smoothing out interesting details. The original three Vs of big data impose shallow processing for scalability. It is still an open challenge to design scalable process to filter (project or denoise, however a volume reduction strategy may be based on) the data to lower volumes and enable more effective analysis. In parallel, distributed infrastructures accommodating hierarchical processing of the data may help finding the essence of information and focus on these sparse *interesting needles* in the *data haystack*. It is also a commonplace that the potential of big data for business profitability is more an intuition than a frequent reality[7]. Hence,

[7] https://www.facebook.com/dan.ariely/posts/904383595868

not only effective processing and efficient infrastructures are needed but also the right analysis models are still lacking.

The ubiquity of communication platforms and networks have shaped the culture and raised new concerns and approaches towards privacy and security issues. Further deployments are likely to be guided by the further integration of connected hardware into our everyday lives. The news ways of interacting with the data that these devices create may be exploited for further augmenting the ubiquity and usefulness of the data for the customer. In turn, these powerful sensing devices will enable companies to tailor recommendation and targeting systems even further. Where the original Web was about simple data, the Web 2.0 about people and their relationships, the emergent *web of things* (suggested as "Web 3.0") proposes to connect "Anything, Anywhere, Anytime". Objects will be part of the communication process and their usage, location, proximity, *etc* will be tracked for better user behavior understanding. Extending the concept of *Tangible User Interface*, devices may symbol any data or virtual entity and be moved, exchanged, or combined as any object can be, with an associated impact in the virtual world.

Affective computing (Picard 2000), assessing user emotions via physiological sensors will also allow providers to penetrate even further into users' wishes. The trade-off between privacy and utility is thus very likely to continue evolving.

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# Data-Driven Decisions in Service Engineering and Management

*Today, the frontier for using data to make business decisions has shifted, and high-performing service companies are building their competitive strategies around data-driven insights that produce impressive business results. In principle, the ever-growing amount of available data would allow for deriving increasingly precise forecasts and optimised input for planning and decision models. However, the complexity resulting from considering large volumes of high-dimensional, fine-grained, and noisy data in mathematical models leads to the fact that dependencies and developments are not found, algorithms do not scale, and traditional statistics as well as data-mining techniques collapse because of the well-known curse of dimensionality. Hence, in order to make big data actionable, the intelligent reduction of vast amounts of data to problem-relevant features is necessary and advances are required at the intersection of economic theories, service management, dimensionality reduction, advanced analytics, robust prediction, and computational methods to solve managerial decisions and planning problems.*

## 1 Introduction

Increasingly automated data capturing, the ubiquity of sensors, the spread of smart phones, and the penetration of life by social media leads to enormous and ever growing amounts of data. Novel technological advances in analytics and scalable data management promise to facilitate the capturing, storage, searching, sharing, analysing, and visualisation of relationships and trends hidden in large, high-dimensional data sets.

While, traditionally, scientists in areas such as meteorology, genomics, physic simulations, or environmental research were primarily faced with the challenges of exploring large, very high-dimensional data sets, today such challenges also affect areas like business informatics. In particular service design and management need to process data in order to spot business trends, determine and anticipate bottlenecks and quality of service, or prevent customer churn by identifying churn risk and triggering appropriate actions, to name only a few tasks. In general, enterprises that can use their data quickly and correctly can gain efficiency through data-driven decisions, anticipatory action and accelerated service support and delivery processes. As an example, those companies can utilise knowledge extracted from past customer behaviours to better understand customers in order to better convince them with smart, individualised offers and services.

### 1.1 Service Management

Traditionally, the aim of service management is to optimise service-intensive supply chains, which are typically much more complex than the supply chains of typical goods. Those require tighter integration with field service and third parties and must also accommodate inconsistent and uncertain demand by establishing more integrated and more robust information flows. In addition, most processes must be coordinated across numerous service locations. Interestingly, among typical manufacturers, after-sale services (support, repair, maintenance, etc.) comprise less than 20% of revenue. Among the most successful companies, those same activities on average generate more than 50 percent of their total profits

(Accenture 2006). This is one of many observations indicating that a profound understanding of customers and business partners and establishing high-quality service and information management is of crucial importance.

However, today enterprises provide an increasing number of services in an automated or semi-automated fashion by means of information technology (IT services), where customer behaviour and experience can only be 'observed' by tracking what a customer is doing, in particular how he uses one or more services over time. Providers even of IT-only services can no longer afford to focus on technology and their internal organisation, but need to consider the quality of the services they provide and focus on the relationship with customers. IT service management (ITSM) refers to the implementation and management of high quality IT services that meet the needs of customers. ITSM is performed by IT service providers through an appropriate mix of people, process and information technology (Office of Government Commerce (OGC) 2009).

Unfortunately, in particular with IT services, providers typically do not receive regular direct customer feedback that is required for marketing, further service improvements, and service innovation. However, there is an ever-growing amount of information how a customer uses a services (e.g., sensors of a rental car, log files of a Web-shop, browsing behaviour in on-line manuals, etc.), and these datasets can be analysed to get 'implicit' feedback as described for example in Choi and Ahn (2009).

### 1.2 Advanced Analytics

In fact, today's service enterprises have more data at hand about their markets, customers, and rivals than ever before. Analysing those vast amounts of historical and current data in an autonomic or semi-autonomic fashion allows for predicting service demand and usage, customer behaviour, and market dynamics. In addition, it allows for identifying novelty patterns in customer behaviour and improving short and long-term performance of enterprise business systems, which is vital for running a competitive service company.

In 'Competing on Analytics: The New Science of Winning', Davenport and Harris (2006) argue that the frontier for using data to make business decisions has shifted. Many high-performing companies are building their competitive strategies around data-driven insights that generate impressive business results. Those companies use advanced analytical procedures, sophisticated quantitative and statistical analysis and predictive modelling. Examples of analytics are the usage of novel tools to determine the most profitable customers and offer them the right price, to accelerate product innovation, to optimise and integrate supply chains, and to identify the major drivers of financial performance. Many examples from organisations such as Amazon, Barclay's, Capital One, Harrah's, and Procter & Gamble are presented, showing how to leverage analytics to drive business. However, various potential definitions for advanced analytics exist. Typically, the 'advanced' indicates quantitative, predictive or prescriptive models as described later in this paper.

### 1.3 Big Data Analytics

Over the last two years, the term Big data is propagated by major companies offering information management software such as Intel[1], SAP[2], or IBM[3], and has become more and more a synonym for data analysis and advanced analytics. For many SMEs and also for larger companies, this is in some sense counter-productive as nowadays enterprises collect massive amounts

[1]http://www.intel.de/content/www/de/de/big-data/big-data-analytics-turning-big-data-into-intelligence.html

[2]http://www54.sap.com/pc/tech/in-memory-computing/hana/software/analytics/big-data.html

[3]http://www-01.ibm.com/software/data/infosphere/hadoop/what-is-big-data-analytics.html

of various metrics, such as historical sensor, monitoring, and customer usage data, hoping that the data will turn out to be useful one day for prediction and optimisation.

Accordingly, as Big data analytics is now a popular topic for management, many information management companies offer tools and solutions to extract and project relationships between a vast amount of high-dimensional data vectors (structured, semi-structured, or unstructured ones), and to process, reduce, correlate and interpret data in a much more flexible fashion compared to traditional database management and business intelligence systems.

Over the last years, enterprises such as Software AG, Oracle, IBM, Microsoft, SAP, EMC, and HP have spent more than $15 billion on software firms only specialising in data management and analytics. Since the last three years, this industry was worth more than 100 billion US-dollars and was growing at around 10 percent a year: about twice as fast as the software business in general (The Economist 2010).

### 1.4 The Curse of Dimensionality

While in principle the vast and ever-growing sets of available data would allow for deriving increasingly precise predictions and optimised planning and decision models, the complexity resulting from the consideration of large volumes of multivariate, fine-grained, often noisy and incomplete data leads to the fact that relationships within the data are not found, algorithms do not scale, and traditional statistics as well as data-mining techniques collapse because of the well-known curse of dimensionality (nowadays also called the curse of big data) (Bellman 1961; Lee and Verleysen 2007).

Despite these dimensionality-intrinsic problems, biases in how data are collected, a lack of context, gaps in what's gathered, artefacts of how data are processed and the overall cognitive biases that lead even experienced researchers to determine non-existing patterns (and vice versa) shows that even if a company has Big Data, making use of such data typically not only requires appropriate tools but also data scientists with expertise and know-how, hacking-skills, domain knowledge, and deep mathematical and data management skills; unfortunately, as of yet data scientists of that sort are still a very scarce human resource (Davenport and Patil 2012).

The result is that – in practice – data are often collected and then ignored or aggregated in a problem-agnostic fashion, and finally for most problems rather simple and conservative solution heuristics are applied by rules of thumb or using coarsened data. The authors of this article are not aware of many companies besides the financial institutions and telecommunications companies that make excessive use of their collected data; however, most enterprises spend an increasing amount of money and effort in monitoring systems and data collection. That is also the outcome of numerous studies and expert interviews conducted and summarised by Ross et al. (2013).

Interestingly, already today leading data scientists are telling us that Big Data can and must be reduced intelligently to small data, so that finally for most decision problems one does not need Big Data at all.[4,5]

### 1.5 Collecting the Right (Amount) of Data

Large, global companies already recognise that there is a need to stop collecting more data and start a focused collection of *the right* data required to make decisions and to run a business successfully (Nokia Siemens Networks 2013).

Suppose a company is gathering the right data: attributes and dimensions really relevant for planning and decision-making. There is still the question whether the return on adding more data

[4] Big Data: Maybe You Don't Need It : http://www.datacenterjournal.com/it/big-data-dont/

[5] Most data isn't big, and businesses are wasting money pretending it is:
http://qz.com/81661/most-data-isnt
-big-and-businesses-are-wasting-
money-pretending-it-is/

points diminishes after passing a certain volume of data collection, or certain data granularities (such as monitoring intervals), and if – in a particular situation – gathering additional data will cost more than it will actually yield.

Cleary, an answer to that question depends on the concrete enterprise planning and decision problem, the importance of the problem, the scalability of engines/algorithms processing the data, the tolerance of the algorithms regarding artifacts and noise, the skills of the managers processing and interpreting the data, and many more factors.

However, independent of particular problems and individual factors as aforementioned, the answer also depends on purely statistical or mathematical criteria regarding redundancy and noise within the datasets. That is because such criteria can determine if another piece of data can bring novel information at all, or whether it can be fully or approximately derived from data already available (for example by means of collaborative mechanisms such as regression or causal reasoning).

Furthermore, for reasons of robustness and scalability it is disadvantageous to parametrise prediction models and mathematical decision programs with correlated or even collinear data vectors. In fact, efficient decision mechanisms should be rather elastic and adaptable to the anatomy and the information contained in the input data, while today typically the signatures and internal algorithms of enterprise decision modules are of rather static nature.

Consider a resource allocation mechanism for enterprise services in a data centre. If demand forecasts were expected to be highly precise for certain indicators over a defined period of time, a rather aggressive allocation mechanism operating with deterministic demand curves would be appropriate. Once the demand prediction tool downgrades its confidence levels and shrinks the horizon of the look-ahead period considered as reliable, more conservative allocation mechanisms might be appropriate.

If the forecasting horizon approaches zero time intervals, conservative online mechanism should be applied that allow for handling unexpected demand phases immediately, as sophisticated offline-planning would not beneficial in such situations: plans would be invalid shortly after their computation.

This paper reviews theory and practice of data reduction in service management with regard to the various targets addressed with the different data reduction techniques. First, we argue that a really efficient and intelligent data reduction requires the prior definition of business problems and algorithms how to address these problems with reduced data. Second, we argue that mathematical programs and algorithms for planning and decision-making should not be applied in a data-agnostic fashion. In contrast, programs and algorithms should be sensitive and adjustable to available data and the amount of dependencies, reliability, and stochastics within data, which typically vary over time, use-case, domain, and planning horizon.

## 2 Data Understanding and Reduction

The first and most important step in analytics is a proper understanding of the available data, the involved variables and how these are measured. Data quality, appropriate data cleaning and handling missing values as well as detecting outliers and errors must be performed prior to any data analysis. Knowing that data preprocessing is arguable the most complex and time-consuming step in analytics, for now we assume these tasks have been already performed.

We will now characterise various techniques to reduce data to relevant features, structures, and developments. In order to separate approaches aimed at descriptive, predictive, and prescriptive analytics, we will group the techniques accordingly. Descriptive analytics will be further differentiated in simple aggregations (Sect. 2.1), and approaches that exploit statistical dependencies in and between data objects and variables (Sect. 2.2). In Sect. 2.3, we focus on data mining approaches aimed at gaining knowledge from the data to reduce uncertainty regarding the realisation of a particular variable (or label). A typical task would be the determination of the probability of a positive response of a customer, and the determination of data (features) necessary to learn this probability. In Sect. 2.4 we then summarise approaches to predict whole vectors or time series. Finally, in Sect. 2.5, we focus on prescriptive data reduction techniques that differ from prescriptive techniques as data selection and reduction needs to be aligned with a particular, potentially combinatorial and computational very complex mathematical optimisation problem. In the latter case, the goal is not only to gain insights and reduce uncertainty of future values of data, but to select and transform data in a way that is beneficial for solving a particular planning and decision problem

### 2.1 Data Aggregation for Descriptive Service Analytics

The purpose of aggregating data for descriptive service analytics is to summarise what happened in the past. For example, in Web analytics metrics are considered such as *number of page views*, *conversion rates*, *check-ins*, *churns*, etc. There are literally thousands of such metrics, on their own typically simple event counters. Other aggregations for descriptive service analytics might be the results of simple arithmetic operations, such as *share of voice*, *average throughput*, *average number of positive responds to a campaign*, etc. Most of what the industry called analytics is nothing but applying filters on the data before computing the descriptive statistics, sometimes combined with a linear statistical forecast. For example, by applying a geo-filter first, a company can get metrics such as average revenue per week from USA vs. average revenue per week from Europe. Structuring aggregated data to reports derives the well established and broadly used reporting functions based on information stored in data warehouses. Management dashboards usually provide the means of presenting such aggregated data to managers to support their business decisions.

### 2.2 Data Compression and Approximation

The most generic way to reduce (and not just aggregate) data is to exploit dependencies in and between data vectors – in a problem-agnostic way – by multivariate statistics and matrix approximation techniques, mostly based on linear algebra. Examples are variance-preserving approximation techniques such as *Empirical Orthogonal Defactorisation* derived by *Eigen-approaches* such as *Truncated Singular Value Decomposition* or *compact Principal Component Analysis* (*PCA*). More and more, techniques such as *Independent Component Analysis* (*ICA*) are applied to derive more meaningful features (in contrast to solely reducing data). By exploiting communalities, such techniques are very useful to reduce data to the maximum amount of variation (as a proxy for information) in the data sets and are often shown to derive the best low-dimensional approximation of data in very useful mathematical senses such as the $L_2$ norm.

Other examples are topology-preserving techniques such as *Local-Linear-Embedding* (*LLE*) (Roweis and Saul 2000) or *isoMap* (Tenenbaum et al. 2000), where the objective of data reduction is not to capture maximum variance of the data sets with fewer dimensions, but to preserve the topology of the data objects, i.e., their distance relationships.

Likewise, multivariate techniques such as vector quantisation and linear and non-linear regression techniques fall into this category of data reduction according to pre-defined mathematical objectives.

### 2.3 Data Reduction by Information Gain and other Criteria

Unlike the approaches described in Sect. 2.1 and Sect. 2.2, the analysis step of discovering knowledge in databases is aimed at discovering patterns in sets of data involving methods at the intersection of artificial intelligence, machine learning, statistics, and database systems. The overall goal is to extract pattern in a data set and transform it into structural dependencies for further use. Aside from the raw analysis step, it involves database and data management aspects, inference considerations, interestingness metrics, complexity considerations, post-processing of identified structures, visualisation, and on-line updating mechanisms.

Typical goals are the automatic or semi-automatic analyses of large quantities of data to extract previously unknown patterns such as groups of data records (segmentation analysis), unusual records (anomaly detection) and dependencies via association rules, decision trees, or other methods. For instance, data mining techniques might identify multiple groups in the data, which can then be used to obtain more accurate prediction results and more focused marketing campaigns by a decision support system. Here, data is reduced to gain information about the general structure of the data (clustering), or the class prediction of records with an unknown label due to similarities with other records where labels are already known.

As discussed in Sect. 1.4, clustering and classification do not perform well with high-dimensional data because of the curse of dimensionality. Beyer et al. (1999) and Aggarwal et al. (2001), amongst others, have shown that standard measures for proximity or distance that are used for standard *k-means clustering*, are becoming more and more meaningless with growing dimensionality. To circumvent this problem, approaches as proposed in Aggarwal et al. (2001) introduce novel distance calculations that are still meaningfull even in high-dimensional data space of 15 dimensions and more. Alternative streams of research (see Tsymbal et al. 2002 as an example) propose approaches that do not work (cluster) on original data but on reduced data as a result of compression steps as described in Sect. 2.2.

### 2.4 Data Reduction for Predictive Service Analytics

Predictive analytics is based on information extracted by the three previous data understanding and reduction steps; it uses all of the gained insights to make robust prediction of developments of important indicators, metrics, and variables (Stewart et al. 2012).

An intuitive way to understand predictive analytics is to apply it to the time domain. The most familiar predictive analytic tool is a time series model (or any temporal model) that summarises past trajectories found in the data, and use either auto- or (lagged) cross-correlations and regression to extrapolate time series to a future time where data is not yet existing. This extrapolation in the time domain is what scientists refer to as forecasting or prediction.

Although predicting the future is a common use case of predictive analytics, predictive models are not limited to predictions in temporal dimensions. Such models can theoretically predict anything and, hence, predictive analytics are somewhat overlapping with data mining and knowledge extraction as described in Sect. 2.3. The predictive power of a model needs to be properly validated by criteria addressing the robustness of the prediction such as using pre-whitened predictors, perpendicularity of predictors, by using information criteria such as BIC or AIC, and finally out-of-sample testing using consecutive samples. The essence of predictive analytics, in general, is that we use existing data to build a model. Then we use the model to predict data that doesn't (yet) exist.

However, only with concrete use cases in terms of business problems in mind, one can decide which pieces of information in the data set are ultimately relevant for a company, and which pieces are not. This brings one directly to data reduction for prescriptive analytics that will be described in the next subsection.

### 2.5 Data Reduction for Prescriptive Service Analytics

Prescriptive analytics not only predicts a possible future, it predicts multiple futures based on the decision maker's actions. Therefore a prescriptive model is, by definition, also predictive and significant effort must be undertaken to guarantee internal and external model validity. As it is seen today, a prescriptive model is actually a combination of multiple predictive models running in parallel, one for each possible input. Since a prescriptive model is able to predict the possible consequences based on different choices of action, it can also recommend the best course of action for any pre-specified outcome, given the data set used to predict the future (together with its confidence or uncertainty). The goal of most prescriptive analytics is to guide the decision maker towards decisions that will ultimately lead to an (near) optimal and robust business outcome.

In prescriptive analytics, one also builds a predictive data model. However, the model must have two more added components in order to be prescriptive. A company not only needs a rigorously validated predictive model, the model must be actionable, i.e., managers must be able to take actions supported by the model. In addition, the prescriptive model must have a feedback system that collects feedback data for each type of action, which will additionally increase data volume by some orders of magnitude. Therefore, prescriptive analytics is very challenging even with scalable data infrastructures and the talent/expertise to make sense of the feedback data (e.g., sensitivity analysis, causal inference, or risk models).

That makes prior data reduction even more important and requires a focus on the pieces of input data really relevant for decision-making and optimisation.

## 3 Information Gain versus Optimisation Gain

Each department of a service provider has a set of typical tasks to perform on an operational, tactical, or strategic level. Taking for instance the Customer Relationship Management (CRM) department. CRM is aimed at the optimisation of a company's interactions with current and future customers. Objectives of CRM are the reduction of overall churn by adequate customer service and support, or by identifying and rewarding customers that have been loyal over a period of time but now show certain behaviours that increase churn probability (reduced call frequency, churns of neighbor nodes in the telecommunication network, etc.) Another objective might be the identification of customer segments for particular campaigns such as cross-selling offers based on score-values of customers. Scores are derived by data analytics and reflect the probability of a certain customer to respond positively depending on a customer's profile and past behaviour. Such procedures are aimed at gaining information from datasets regarding the probability of an unknown label in data records (for instance, class predictions such as churn: yes/no, upselling: yes/no, etc.) and are in the primary focus of business intelligence solutions.

However, usually strict business rules exist that complicate the selection of target customers. As a simple example, consider the case where one single customer is not allowed to be contacted more than twice a year (a common rule-type in telecommunications companies' campaign management). This in fact leads to predictive and finally to prescriptive analytics, as combinatorial decision problems based on expected behavioural developments of customers are required (beyond the calculation of current scores). Besides a customer's score-value for a planned campaign, knowledge of future campaigns are of importance as well as on future developments of customers in order to predict their responses. In addition, it has been shown by Goel and Goldstein (2013), amongst others, that the structure of the communication or social network and the prediction of future behaviour of a customer's neighbors play important roles, which brings a decision maker to network models, multivariate forecasting models and collaborative prediction.

While there is a huge body of knowledge of broadly used methods and sophisticated tools exist to perform individual tasks such as classification, time series prediction, or mathematical optimisation, the integration of these tasks to derive efficient and robust overall solutions is still left to the expertise and preferences of individual decision makers, typically based on trial-and-error procedures or rules of thumb.

For each task, different data reduction techniques and feature-combination might be adequate, while the interplay of these tasks might lead to the fact that certain data considered as highly relevant in one task might not or only slightly impact the overall solution (and vice versa). For instance, it might turn out that the prediction of features relevant to compute current scores are too difficult to predict for future campaigns and the forecast cannot be considered as reliable. Formulating a stochastic optimisation model might reveal that the solution is highly sensitive to even small planning errors or rather insensible to larger ones, which makes the predictability of a feature either less or more important. Hence, each type of problem requires individual data and model selection procedures if the goal is to make optimal decisions.

This leads to a novel concept in prescriptive analytics that we will refer to as *optimisation gain* of data. Optimisation gain differs from information gain (or derivatives such as information gain rations, GINI, etc.) or matrix approximation quality norms of a residual matrix. Those metrics are aimed at quantifying the quality of a data prediction or approximation without contextual knowledge on how information is used in subsequent optimisation steps.

By optimisation gain we mean the dependency of a solution (the solution quality) derived by a mathematical model or algorithm to additional data, which might be more fine-grained data, more data in terms of a longer reliable planning horizon, or simply an additional attribute or dimension under consideration.

Optimisation gain also differs from concepts such as sensitivity, robustness, or stability of a solution. With optimisation gain we address the different and more general problem of quantifying, if (and how much) the optimality or robustness of a solution would benefit for example from the consideration of a novel data feature in a particular planning or decision problem. Addressing such questions is challenging as this typically requires the re-formulation of the mathematical program formulation for numerous input-data combinations and transformations. The intuition of optimisation gain is the quantification of the solution quality expected with different input data for a particular type of optimisation problem analytically, without expensive and time-consuming (and potentially infeasible) trial-and-error-procedures. The vision is a new generation of criteria by integrating data and model selection and configuration.

Please notice that optimisation gain can become negative as too many parameters can lead to an explosion of the search spaces and increased complexity, where optimal solutions are much harder to find. For instance, node-sets of branch & cut solvers might increase dramatically, and the quality of solutions that can be found in pre-defined periods of time might decline sharply with the number of features and constraints under consideration. Furthermore, models operating with too many data dimensions are more likely subject to over-fitting as artefacts and collinear configurations of (stochastic) variables used as model-input worsen the quality of decision-making. From a business perspective, the marginal gain of considering more data might further decline as collecting and managing data comes at additional costs for data scientists that need to analyse the data, as well as costs for monitoring, IT infrastructures, storage, and licenses.

We argue that the role of optimisation gain of data is a highly relevant concept in prescriptive analytics, and key to reducing Big Data efficiently to a manageable and actionable set of features Also, INFORMS, the leading scientific and professional organisation for OR professionals, decided to stake its claim on the analytics movement. The organisation recognised that the trend toward data-driven and analytical decision-making presents tremendous opportunities and challenges for OR professionals (Libertore and Luo 2011). Since 2009, INFORMS organises an own conference at the intersection of analytics and OR named *Business Analytics and Operations Research*, with a focus on how to apply data science to 'the art of' business optimisation. It features presentations on real-world applications of analytic solutions, presented by industry and university leaders.

Optimisation gain can provide a means of significantly reduce the effort spent for monitoring, collecting and managing data, as ideally only data is collected that is indeed supposed to improve decisions. Unnecessary frequent measurements are also avoided as the collection of correlated data that is (statistically) already captured by other variables. These ideas are closely related to visions such as smart measurement and collaborative monitoring systems, but with an additional focus on the impact on the business relevance of gathered data. We will further detail on this in Sect. 4.

## 4 Feature-based Optimisation and Model-Data-Integration

As aforementioned, certain units in enterprises have specific tasks to perform, usually composed by structured or at least semi-structures processes. For instance, in IT service management, the role of capacity management is to ensure sufficient capacity to provide high-quality services to customers efficiently, i.e., at reasonable (low) costs to the business. In capacity management, it is important to have a clear picture of the expected service demand and the corresponding resource demand that needs to be supplied in future points of time. Considering the case of private clouds, with the potential of hosting services in virtual machines (VM) in a flexible manner, e.g., by co-hosting VMs temporarily on the same physical server, sharing and multiplexing a servers capacity for resources such as CPU, memory, or I/O. In such an environment, IT service managers try to minimise the number of servers by assigning enterprise services in virtual machines efficiently to physical servers, but at the same time provide sufficient computing resources at each point in time. It is worthwhile to notice that running servers are (independent of their utilisation levels) the main energy drivers in data centers, where energy costs already account for 50% or even more of total operational costs (Filani et al. 2008).

Without going into too much detail, the resulting VM allocation problem can be reduced to a stochastic multi-dimensional bin-packing problem, a well-known NP-hard problem. As it is the case with every bin-packing problem, the goal is to fill-up the available spaces (resource capacities) of bins (servers) as much as possible, and, hence, come out with fewer servers while not exceeding the capacity of servers, as this would result in overload and SLA violations.

Theoretically, historical workload data would allow for accurate workload demand forecasting (for more than 80% of typical operational business services) and optimal allocation of enterprise applications to servers. In various experiments and studies with smaller VM sets it has been shown that such approaches lead to a reduction of required server by around 30% (Speitkamp and Bichler 2010). Unfortunately the volume of data and the large number of resulting capacity constraints in a mathematical problem formulation renders this task impossible for any but small instances and is of little use for IT service providers with server parks of hundreds or thousands of VMs to be consolidated.

Looking at the core of each packing problem, in particular at bin-packing problems, the challenge is to find complementarity in objects to be packed (in our case, the demand profiles of VMs for various resources over time) to achieve high average server utilisation levels. It makes sense to co-host VMs with peak loads in the morning hours and VM having their peak loads later during a day. Similarly it makes sense to combine a VM with high CPU and low memory demand with one having lower CPU but high memory demand.

When we consider relevant features of workload profiles for the packing problem as aforementioned, features describing the complementarities between VM profiles could be of great value, besides features describing the absolute resource demand curves of VMs.

Setzer and Bichler (2012) use techniques based on singular value decomposition (SVD) to extract significant features from a matrix of the expected (fine-grained) demand vectors of hundreds of VMs and provide a new geometric interpretation of these features as principal demand patterns, complementary between these patterns, and uncertainty. The extracted features allow for formulating a much smaller allocation model based on integer programming and allocating large sets of applications efficiently to physical servers. While SVD is typically applied for analytical purposes only such as time series decomposition, noise filtering, or clustering, here features are used to transform a high-dimensional allocation problem in a low-dimensional integer program with only the extracted features in a much smaller constraint matrix. The approach has been evaluated using workload data from a large IT service provider and results show that it leads to high solution quality. At the same time it allows for solving considerably larger problem instances than what would be possible without prescriptive analytics, intelligent data reduction and model transform. This work provides a first example of a highly integrated data reduction and optimisation approach.

The same authors argue that the overall approach can also be applied to other large packing problems. For instance, in Setzer (2013), the authors show that high-dimensional knapsack problems can also be intelligently reduced to smaller and computationally tractable ones, as long as there is a significant amount of shared variance amongst the dimensions to be considered. Please notice that, according to recent studies, knapsack-problems are amongst the top four problems to be solved in enterprises, although managers often do not know that their particular problems could be formulated as knapsack-problems.

Overall, we believe that there is a huge potential for solving particular decision problem with Big Data made small. However, to exploit these potentials, problems must be formalised before integrated data reduction and optimisation models can be developed.

Reconsidering the example of capacity management in private cloud infrastructures, we will now detail on the need for a decision model fabric that not only aligns the model to be used to changing environments by considering novel parameters. In contrast, completely different solution techniques are required depending on the (recent) structures and developments found in the data. Again, we will use private clouds for illustration.

Nowadays, live migration allows to move VMs to other servers reliably even during runtime and promises further efficiency gains (VMWare ESX, amongst others) (Nelson et al. 2005). Some platforms such as VMware or vSphere closely monitor the server infrastructure in order to detect resource bottlenecks by tracking threshold-violations. If such a bottleneck is detected they take actions to dissolve it by migrating VMs to different servers. For instance, if the CPU utilisation exceeds 80%, a VM is migrated away from that server to reduce total server load. On the other hand, if a controller detects phases of low overall workload, there is the possibility to concentrate workloads on fewer servers by vacating servers and shutting down these source servers temporarily to further reduce energy consumption. We will refer to such techniques as dynamic resource allocation or dynamic control, as opposed to static VM allocation where allocations are computed and kept fixed for a longer period of time.

## 5 Towards Data-Elastic Decision-Making

On the one hand, dynamic control strategies are more flexible and should therefore lead to lower energy costs. On the other hand, migrations cause significant additional overheads and response-time peak, which are avoided with static allocation mechanisms. It has been shown that with well-predictable workloads of business applications, dynamic resource allocation during operational business hours does not lead to higher energy efficiency compared to static allocation even if future demand is known only to a certain extend (Wolke et al. 2013). However, if demand is completely unknown, dynamic control is the only reasonable option to avoid both: massive overprovisioning and service degradation. Depending on the share of stochastic developments in workload demand curves, hybrid models might be appropriate where basic allocations are computed for a given planning horizon in a more conservative fashion, considering the option of potential migrations to cope with uncertainty.

In summary, dynamic, data-based model selection is required that differs from parameter alignment, which simply would mean that for instance the alpha parameter in an exponential smoothing model is adjusted from time to time (which then leads to a different and hopefully better short term prediction), but where the same mathematical model is used for prediction.

In the example above, depending on the predictability of demand behaviour, which might be well predictable throughout certain periods but rather unpredictable in other periods of time, completely different allocation mechanisms are advised.

## 6 Conclusion and Vision

Analysing historical and current data in order to make better predictions is vital for running a competitive service company. Data-driven design and management of services demand interdisciplinary knowledge from the business domain, processes, data analytics, and mathematical optimisation. While in principle the ever-growing amounts of available data would allow for deriving increasingly precise forecasts and optimised input for planning and decision models, the complexity resulting from the consideration of large volumes of ever-growing volumes of multivariate, fine-grained data leads to the fact that dependencies and relationships within the data are not found, algorithms do not scale, and traditional statistics as well as data-mining techniques collapse because of the well-known curse of dimensionality. Hence, in order to make Big Data actionable, we are interested in the intelligent reduction of vast amounts of data to small sets of problem-relevant features. We argue that mathematical optimisation and planning models need to be transformed to be able to operate efficiently on highly reduced data. In addition, the selection of adequate planning and decision models must be adapted to (current) data and the reliability of relations and predictions extracted from that data, which requires time-dynamic and data-driven model selection and evaluation techniques.

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