Enterprise Modelling in the Digital Age

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Abstract

Our society is transitioning from the industrial age to the digital age. The resulting digital transformation also revolutionises the enterprise landscape. In addition, one can observe how the notion of economic exchange, core to the economy, is shifting from following a goods-dominant logic to a service-dominant logic, putting the focus on continuous *value co-creation* between providers and consumers.

Combined, these trends drive enterprises to transform continuously. During enterprise transformations, *coordination* among the stakeholders involved is key. Enterprise models are traditionally regarded as an effective way to *enable* such (informed) coordination. At the same time, however, the digital age also provides ample challenges, and opportunities, for enterprise modelling.

In line with this, the objective of this chapter is therefore threefold. The first aim is to reflect on the role of enterprise modelling towards the coordination of enterprise transformations in general. The second aim is to explore the challenges, which digital transformations pose to enterprise modelling. The third, and final, aim of this chapter is to reflect on how enterprise modelling itself may benefit from the new digital technologies.

1 Introduction

Our society is transitioning from the industrial age to the digital age. The development and maturation of "digital technologies", such as mobile computing, pervasive computing, cloud computing, big data, artificial intelligence, robotics, social media, etc, further fuel the digital transformation, which now also revolutionises the enterprise landscape.

Where IT originally was a mere supportive tool for administrative purposes, it is safe to say that IT has now become an integral part of an organisation's primary processes, and has quite often become an integral part of the business model. As a result, only considering the *alignmen*t (Henderson and Venkatraman, 1993) of business and IT no longer suffices. The difference between business and IT is increasingly fading; they have been *fused* into one (Gils and Proper, 2018). Companies such as Amazon, AirBnB, Uber, Netflix, Spotify, N26, etcetera, illustrate how IT and business have indeed become fused. The CEO of a major bank can even be quoted as stating "*We want to be a tech company with a banking license*" (Hamers, 2017).

In addition, marketing sciences (Vargo and Lusch, 2008; Grönroos and Ravald, 2011; Lusch and Nambisan, 2015; Vargo and Lusch, 2016) suggests that the notion of economic exchange, core to the economy, has shifted from following a goods-dominant logic to a service-dominant logic. While the former focuses on tangible resources to produce goods and embeds value in the transactions of goods, the latter puts the focus on the continuous *value co-creation* between providers and consumers by way of resource integration. For instance, in the airline industry, jet turbine manufacturers used to follow a classical goods-dominant logic by selling turbines to airlines. However, since airlines are not interested in *owning* turbines, but rather in the realisation of *airtime*, manufacturers nowadays sell airtime to airlines instead of jet turbines. *Value co-creation* is shaping up as a key design concern for modern day enterprises (Gils and Proper, 2018).

These intertwined, and mutually amplifying, trends drive enterprises to transform continuously. As discussed in (Proper et al., 2018b), *coordination* among the stakeholders involved is key during such transformations. More specifically, a shared understanding, agreement, and commitment, is needed on (1) what the overall strategy of the enterprise is, (2) the current affairs of the enterprise, i.e. the current situation, as well as the relevant history leading up to it, and possible trends towards the future, (3) the current affairs of the context of the enterprise, and (4) what (given the latter) the ideal future affairs of the enterprise are.

Enterprise models, and ultimately enterprise (architecture) modelling languages and associated frameworks, are generally regarded as an effective way to *enable* such (informed) coordination. At the same time, however, the digital age also provides ample challenges, and opportunities, for enterprise modelling.

In line with this, the objective of this chapter is threefold. The first aim, addressed in section 2, is to reflect on the role of enterprise modelling towards the coordination of enterprise transformations in general. With this as a base, we then turn our focus to the transition to the digital age. In line with this, the second aim of this chapter, addressed in section 3, is to explore the challenges, which digital transformations pose to enterprise modelling. The third, aim of this chapter, covered in section 4, is to also reflect on how enterprise modelling itself may benefit from the new digital technologies.

2 The role of enterprise modelling

In discussing the role of enterprise modelling in enterprise transformations in general, and digital transformations in particular, we will start by discussing the concepts of enterprise and model as such. Based on this understanding, we then address the important question of the *purpose* of enterprise modelling. As enterprise models are used in a coordinative context involving many different stakeholders, we will finish this section with a discussion on the collaborative dimension of enterprise modelling.

2.1 Enterprises

In defining the concept of enterprise, we start out from the concept of *organisation*. An organisation is a configuration of resources (social, digital and physical) and activities in pursued of a purpose (Magalhães and Proper, 2017). As such, it is considered to be an invisible construct used to harness and direct the energy of the people who do the work. It exists when people interact with one another to perform essential functions that help to attain goals (Daft, 2007; Kates and Galbraith, 2007). This definition includes commercial businesses, government agencies, etc, but also includes *networks of organisations* (Friedman, 2005; Umar, 2005), such as joint ventures, entire product / service supply chains, etc.

The *purpose* of an organisation and the systematic way it endeavours to achieve this purpose can be regarded as its *enterprise*, in line with the definition provided by the dictionary: "*a systematic purposeful activity*" (Meriam-Webster, 2003). As such, an organisation can engage in multiple enterprises, and can even do so in collaboration with other organisations.

2.2 Models

Several scholars within the field of systems modelling (including information modelling, enterprise modelling, software modelling) have provided definitions of the concept of model (Stachowiak, 1973; Rothenberg, 1989; Frank, 1998; Falkenberg et al., 1998; Hoppenbrouwers et al., 2005; Bézivin, 2005; Mahr, 2011; Thalheim, 2011; Bjeković et al., 2013). Most of these definitions are based on the well-known *semiotic triangle* (Ogden and Richards, 1923), as depicted in Figure 1.

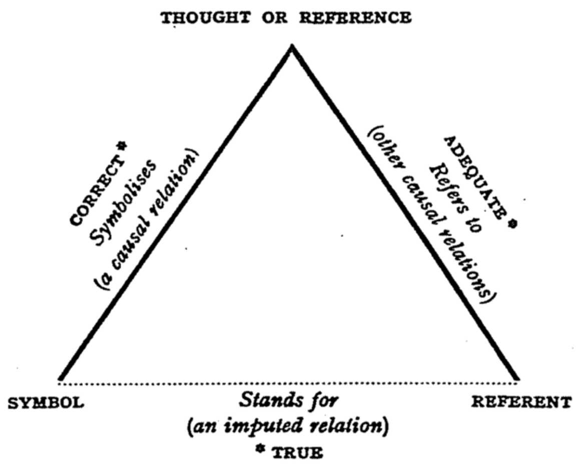

Figure 1: The semiotic triangle (Ogden and Richards, 1923)

The semiotic triangle expresses how a person attributes meaning (*thought or reference*) to the *combination* of a *symbol* and a *referent*, where the former is some language utterance, and the latter is something that the person can refer to. The *referent* can be anything, e.g. something in the physical world (tree, car, bike, atom, document, picture, etc) or something in the social world (marriage, mortgage, trust, value, etc). Next to that, it can be something in an existing world, or in a desired / imagined world.

The semiotic triangle is often used as a base to theorise about meaning in the context of language (Morris, 1946; Ullmann, 1967; Searle, 1979; Cruse, 2000), and is essentially a continuation of the work by C.S. Peirce (Peirce, 1969). Based on this linguistic background, the semiotic triangle has also been used, directly or indirectly, by several authors to reason about the foundations of (information) systems modelling (Stamper, 1996; Krogstie, 2002; Kecheng et al., 2002; Lankhorst et al., 2017b; Guizzardi, 2006; Thalheim, 2011; Thalheim, 2013; Bjeković et al., 2012).

In line with the semiotic triangle, we define a model as (Bjeković et al., 2012): "*an artefact that is acknowledged by an observer as representing some domain for a particular purpose*", where '*observer*' refers to the (group of) actor(s) involved in the creation and use of the model, and '*domain*' can be any '*part*' or '*aspect*' of the past / existing / desired / imagined world.

2.3 The purpose(s) of enterprise modelling

During any enterprise transformation, *coordination* among the key stakeholders and the projects / activities that drive the transformations is key (Proper et al., 2018b). A shared understanding, agreement, and commitment, is needed on (1) what the overall strategy of the enterprise is, (2) the current affairs of the enterprise, i.e. the current situation, as well as the relevant history leading up to it, and possible trends towards the future, (3) the current affairs of the context of the enterprise, and (4) what (given the latter) the ideal future affairs of the enterprise are.

Models, and ultimately enterprise modelling languages, are generally considered as an effective way to support such coordination, in particular by enabling *informed decision making* (Op 't Land et al., 2008; Harmsen et al., 2009; Proper, 2014) and *informed sensemaking* (Proper and Lankhorst, 2014) (in the sense of Weick, 1995).

Enterprise models can zoom in on, or relate, different aspects of an enterprise, including its structures, purpose, value proposition, value propositions, business processes, stakeholder goals, information systems, underlying IT infrastructures, physical infrastructure, etc. Many languages and frameworks have indeed been suggested as a way to create and capture a different enterprise models. Examples include: BPMN (Freund and Rücker, 2012), UML (Object Management Group, 2010), ArchiMate (Lankhorst et al., 2017a; Band et al., 2016), 4EM (Sandkuhl et al., 2014), MEMO (Frank, 2002) and MERODE (Snoeck, 2014).

In general, enterprise models can be created for different overall purposes, including:

1. *Understand* – Understand the working of the current affairs of an enterprise and / or its environment.
2. *Assess* – Assess (a part / aspect of) the current affairs of an enterprise in relation to a e.g. benchmark or a reference model.
3. *Diagnose* – Diagnose the causes of an identified problem in the current affairs of an enterprise and / or its environment.
4. *Design* – Express different design alternatives, and analyse properties of the (desired) future affairs of the enterprise.
5. *Realise* – Guidance, specification, or explanation during the realisation of the desired affairs of an enterprise.
6. *Operate* – Guidance, specification, or explanation for the socio-cyber-physical actors involved in the day-to-day operations of an enterprise.
7. *Regulate* – Externally formulated regulation on the operational behaviour of (an) enterprise(s).

Depending on additional factors, such as the abilities of the actors involved in the creation and utilisation of the model, the intended usage of the model, the need for understanding / agreement / commitment to the model from different stakeholders, etc, these overall purposes can be refined further (Proper et al., 2018a).

As the creation of models involves effort, the level to which a model meets its purpose paves the way for its **R**eturn **o**n **M**odelling **E**ffort (RoME, see Chapter 4 of Op 't Land et al., 2008)

2.4 Collaborative enterprise modelling

Enterprise models are quite often created and used in a collaborative context. For example, as discussed in (Proper et al., 2018b), *coordination* among the stakeholders involved is key during enterprise transformations. More specifically, it requires a shared understanding, agreement, and commitment, is needed on (1) what the overall strategy of the enterprise is, (2) the current affairs of the enterprise, i.e. the current situation, as well as the relevant history leading up to it, and possible trends towards the future, (3) the current affairs of the context of the enterprise, and (4) what (given the latter) the ideal future affairs of the enterprise are (Op 't Land et al., 2008; Proper et al., 2018b),.

As a consequence, the collaborative aspects of enterprise modelling are key. The, shared, *understanding* of a model is related to the notion of *model understanding*. Empirical studies have shown that diagrams can easily be misunderstood (Hitchman, 1995; Hitchman, 2002; Nordbotten and Crosby, 1999; Purchase et al., 2002; Masri et al., 2008; Caire et al., 2013), which is likely to lead to problems in practical use. Model understanding has also fuelled the work on e.g. the quality of models and modelling (see e.g. Krogstie et al., 1995; Krogstie, 2002; Bommel et al., 2007; Moody, 2009; van der Linden and Hadar, 2015).

On a more fundamental level, these challenges are also related to the concept of *boundary object* (Levina and Vaast, 2005), which originates from social sciences: "*They have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation. The creation and management of boundary objects is key in developing and maintaining coherence across intersecting social worlds.*" (Star and Griesemer, 1989). The applicability of this concept in the context of enterprise modelling has been explored in e.g. Abraham et al., 2013 and Abraham, 2013.

An early approximation of the concept of boundary object in the context of enterprise modelling can be found in terms of *views* and *viewpoints* (Lankhorst et al., 2017c) that enable the communication on the design of an organisation (and its different aspects) with different groups of stakeholders while respecting "*the language of the stakeholders*" (Proper et al., 2017). In addition, *natural modelling* (Bjeković et al., 2013; Zarwin et al., 2014), as also echoed more recently in the ideas on *grassroots modelling* (Sandkuhl et al., 2018), also aim to enable the involvement of a broader class of stakeholders in modelling activities.

The development of a shared agreement, and commitment, regarding models depends largely on the collaborative processes used in enterprise modelling. This has already triggered the development collaborative and / or participative modelling approaches (Stirna and Persson, 2007; Barjis, 2009; Ssebuggwawo et al., 2009; Sandkuhl et al., 2014). A complementary perspective is offered by the field of collaboration engineering (Briggs et al., 2006; Vreede et al., 2006), which aims to develop different strategies to structure collaborative processes by means of elementary building blocks called 'thinklets'. Results of applying collaboration engineering in the context of enterprise modelling have been reported in e.g. Nabukenya et al., 2009; Nakakawa et al., 2011; Nabukenya et al., 2011 and Nakakawa et al., 2018.

3 Enterprise modelling for digital enterprises

The aim of this section is to explore some of the challenges which the transition to the digital age potentially poses to enterprise modelling. It will do so from five main angles:

1. *Dynamics of the digital age* – As the transition to the digital age revolutionises the enterprise landscape, the dynamics of enterprise transformations has also increased. Enterprises need to be more agile than ever.
2. *Beyond the automation of information processing* – Traditionally, the role of IT in organisation has focussed on the "automation of information processing". The digital age requires a re-think of this. Business models have grown to be digital intensive, while autonomous vehicles and drones, and AI, will drastically change the way work is conducted.
3. *Modelling frameworks for the digital age* – When modelling enterprises, one usually applies some framework to better structure different perspective / abstraction layers. The transition to the digital age makes it all the more important to ensure these frameworks are well structured.
4. *Modelling concepts for the digital age* – The transition to the digital age results in changes of the types new ingredients (AI, sensors, drones, etc) that make up the resulting organisations, and the enterprises they engage in. New modelling concepts are needed to capture these new ingredients.

5. *Data ecosystems* – Finally, as a result of the digitisation, data has become a primary resource. This leads to the need to more explicitly consider the *data ecosystems*, in which the data is gathered, stored, processed, etc.

3.1 The dynamics of the digital age

As the digital age revolutionises the enterprise landscape, enterprises are confronted with wave after wave of digital innovations. This results in a situation in which these enterprises need to work hard to keep their business models (Osterwalder and Pigneur, 2009), and their underlying operating models (Ross et al., 2006), up-to-date and viable. As a result, modern day enterprises needs to be agile (Lankhorst et al., 2012).

In the context of IT, the need for more agility has triggered the emergence of software development approaches, such as Agile, DevOps, etc. One of the key messages from these approaches is to avoid a big-design up front (BDUF), which may sound as a potential threat to enterprise modelling. Nevertheless, enterprise modelling as such is a mere means to an end. In line with the definition of models in general, and enterprise models in particular, as provided in the previous section, an enterprise model is seen as a means to an end (the model's purpose) with a clear (intended) return on modelling effort (see the discussion on RoME in section 2.3).

If the "sketch on the back of a napkin" of a new business process and its underlying IT support, suffices as a design document for an agile project, then this is fine. It would, indeed, imply that this "sketch" is a valid (albeit an ultra-light one) enterprise model fitting its purpose. At the same time, however, one might wonder if a pile of such "sketches" would suffice to conduct an enterprise-wide impact analysis, check compliance to e.g. the EU's GDPR[1] (General Data Protection Regulation), or conduct a well-founded security risk analysis. As such, while a "sketch" might suffice the project goals of an agile project, it might not meet the overall goals of the enterprise, and its ongoing transformations, as a whole (such as coherence management, risk management and compliance). Furthermore, when using a workflow engine to drive the business process, the sketch would still need to be elaborated in terms of a more detailed business process model (which is also an enterprise model) that can be "fed" into the workflow engine.

Whatever the outcome of such a debate, it leads to the need to define situational-factors that defines the purpose, the available resources for (enterprise) modelling efforts, and the potential return on modelling effort. The resulting challenge for the field of enterprise modelling is therefore to provide the means to identify what kind of enterprise modelling is needed in specific situations, including the ability to make a conscious trade-off between local project needs and more enterprise-wide needs to coordinate across enterprise transformations (Proper et al., 2018b).

The tension between the agile needs of development projects, and the need to manage a portfolio of projects as part of a larger enterprise transformation, does result in a need to reflect on the modelling concepts to be used in the different situations. For example, at an enterprise-wide level, it might be better to use so-called architecture principles (Greefhorst and Proper, 2011) to express the overall *direction of change*, rather than the more detailed boxes-and-lines diagrams such as ArchiMate (Band et al., 2016) models. At the same time, the latter type of models are indeed needed to conduct a detailed impact analysis, or a thorough GDPR compliance check. As such, the overall purposes as identified in section 2.3 will likely lead to the use of

[1] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R0679

different modelling concepts. In other words, purpose specific modelling languages (PSML), as a refinement to domain specific modelling languages (DSML).

3.2 Beyond the automation of information processing

Traditionally, the use of IT in organisation started out from the ambition to "automate information processing" (by means of data processing). One would typically (re)design an enterprise by first designing / growing the organisational structures and associated business processes, then consider what information processing would be needed to support these activities, and then finally turn to the question what part of this information processing could be automated. Later, Henderson and Venkatraman (Henderson and Venkatraman, 1993), as well as Tapscott and Caston (Tapscott and Caston, 1993) argued the case that Business and IT should essentially be co-designed, while Hammer (Hammer, 1990) already signalled that automation should not be used to fix structural problems in an organisation.

The digital age brings about the need to further mature this co-design in the sense that now even business models have become digital (Negroponte, 1996; Tapscott, 1996; Tapscott et al., 2000). The business models of companies such as Amazon, AirBnB, Uber, Netflix, Spotify, N26, etcetera, indeed illustrate this point, while, as also mentioned in the introduction, the CEO of a major (traditional) bank can even be quoted as stating "*We want to be a tech company with a banking license*" (Hamers, 2017).

An important aspect in the design of organisations is the division of labour. In other words: *who does what* and *who is responsible for it*? Traditionally, this question focussed on the role of human actors. With the increasing autonomicity of robots, drones, agents, autonomous vehicles, etc, the division of labour increasingly has to include the role of such "digital actors", as well as the collaboration between with the human actors and the digital actors.

3.3 Modelling frameworks for the digital age

In moving beyond "automation of information processing", the transition to the digital age also results in new "ingredients" that make up the socio-technical fabric of modern-day organisations and their enterprises, including the digital actors as discussed above. In (Gils and Proper, 2018), we already explored some of the consequences this may have on enterprise modelling languages such as ArchiMate (Lankhorst et al., 2017a; Band et al., 2016). In this chapter, we take a broader view on this topic, whole not focusing on the possible impact of a specific modelling language.

Enterprise modelling languages usually involve some engineering / architecture framework (Proper and Op 't Land, 2010), defining different perspectives and layers in terms of which an enterprise can be modelled. Examples include ArchiMate (Lankhorst et al., 2017a), Enterprise Ontology (Dietz and Hoogervorst, 2007, TOGAF (The Open Group, 2011), IAF (Wout et al., 2010), and the Zachman framework (Zachman, 1987). These frameworks typically follow the aforementioned "Business-to-IT-stack" line of reasoning, identifying different abstraction layers. However, the abstraction layering(s) used quite often combines different dimensions, leading to confusion.

In (Gils and Proper, 2018) we posited that these frameworks generally use four key mechanisms in creating abstractions (in different dimensions, possibly combining these mechanisms):

1. *Function-construction* – Making a distinction between, *function* referring to the way an enterprise / system is intended to function in light of what users, clients, and other stakeholders might deem useful, and *construction* pertaining to the way it is actually constructed to realise these functions.
2. *Infological support* – Pertaining to the way in which needed "information processing" is realised, e.g. leading to a *business* level involving the activities conducted by an enterprise that have a direct impact in the socio-economical world, an *infological* level (Langefors, 1966) concerned with the information needed / created in the business activities and associated information processing, and a *data* level concerned with the way the latter is realised in terms of underlying data artefacts and associated processing. These levels provide the *why*, *what*, and *how* of (automated) data processing respectively.
3. *Infrastructure usage* – This concerns the fact that one system (of systems), such as an enterprise, can *use* the functions of another system (of systems), where the actual construction of the latter is of no interest to the (designers) of the former (except to the extent of defining service-level agreements). In this case, the latter system (of systems) is considered to be an infrastructure to the former.
4. *Implementation abstraction* – This concerns the gradual / stepwise introduction of details of the (socio-)technical implementation. For example, in IAF (Wout et al., 2010) this materialises in terms of a conceptual, logical, and physical level, while in TOGAF (The Open Group, 2011) this has resulted in the so-called architectural building blocks, and logical building blocks, and in an MDA context (OMG, 2003) in a platform independent model and a platform specific model.

Each of these abstraction mechanisms has a potential added value for enterprise modelling, in particular in the context of digital transformation. It is important to note that these abstraction mechanisms should not be thought of as a set of orthogonal dimensions. On the contrary. The *function-construction* mechanism and *informational support*, or *function-construction* and *infrastructural usage* can be combined easily within one dimension of an engineering / architecture framework. Nevertheless, as discussed in (Gils and Proper, 2018; Proper and Op 't Land, 2010), this should be done carefully and consistently. Even though we do not want to *prescribe* a specific set of dimensions for engineering / architecture frameworks, we do argue that one should ensure a consistent use of the chosen abstraction mechanisms within one dimension.

Consider, for instance, the traditional "Business-to-IT-stack". This stack tends to identify a "business layer", an "application layer" and "technology layer", where the three layers seem to follow the levels of the *infological support* mechanism. However, it seems that in parallel the *implementation abstraction* is partially mixed-in. For example, at ArchiMate's (Lankhorst et al., 2017a) *business layer* one is forced to mix a human-digital agnostic abstraction of business processes (i.e. still abstracting from the choice for human actors or digital actors to "do the work"), together with an elaboration of the human-actor-only parts of the implementation, while the digital-actor-only parts of the implementation are covered by the application layer and technology layer.

Finally, when using a specific engineering / architecture framework one should, of course, not mix the necessary free-flow of a creative design process, and the top-down structuring of the abstraction layers and dimensions contained in the framework (Proper and Op 't Land, 2010). Design choices at a lower level of abstraction, such as choices for technological platforms, may enable / inspire innovations at the higher levels of abstraction. For example, the choice to use "paper" to be "legal tender" representing an amount of gold as stored by a central bank, was an "implementation choice" that enabled a whole range of innovations in the way we deal with money. Similarly, the use of different "digital technologies" (e.g. AI, blockchains, sensors, drones, etc) in the implementation of existing business activities, is likely to trigger a ripple effect of further innovations.

3.4 Modelling concepts for the digital age

In addition to an impact on the modelling frameworks as a whole, the transition to the digital age also results in a need to add new modelling concepts. Below we briefly highlight some of the areas in which we see a need for new modelling concepts. At the same time, we certainly do not claim to be complete.

Moving from the outside in, a first challenge is to include value co-creation considerations in the design of e.g. business models. Existing approaches such as the business model canvas (Osterwalder and Pigneur, 2009) and the complementary value proposition canvas (Osterwalder et al., 2015) focus on value exchange between economic actors in a traditional supplier and consumer role. Value network modelling techniques, such as e3Value (Gordijn and Akkermans, 2003), seem to be better positioned to deal with this shift. However, the shift to value co-creation, requires a re-think of the traditional producer and consumer roles (Chew, 2016), thus leading to a need for new / different modelling concepts (Razo-Zapata et al., 2018; Feltus et al., 2018). Value network modelling techniques, such as e3Value (Gordijn and Akkermans, 2003), seem to be better positioned to deal with this shift.

Moving inward, we arrive at the level of business processes. At this level, one can expect even more impact on the modelling concepts needed as a result of the transition to the digital age. For example, in (Mendling et al., 2018) the authors report on what the possible impact of blockchain on business process management can be, while (Paschek et al., 2017) reports on some of the possible effects of AI on business process management. More generally, as argued in (Gils and Proper, 2018) there is a need to more explicitly position the roles of human actors and digital actors, and their collaboration.

Finally, the transition to the digital age also introduces new risks, as well as the need for regulations (such as the GDPR). To analyse the possible exposure to these risks, and ensure compliance to new regulations, enterprise models can indeed be used (see section 2.3). However, this does require these enterprise models to capture the relevant aspects of an enterprise, thus requiring modelling concepts able to express this (see e.g. Mayer et al., 2015). For example, in the context of the GDPR, this may include aspects such as the location where data is stored, where it is processes, where / how it is gathered (e.g. sensors used), etc.

As argued in (Gils and Proper, 2018), the increase in the number of modelling concepts does require more modular modelling languages, where modelling standards should should focus primarily on providing a generic core of well-defined modelling concepts, in combination with refinement mechanisms that can be used to extend / tailor the core to the needs at hand. The latter may involve both specialisations of the core concepts, as well as e.g. the introduction of (purpose specific / user defined) layers.

3.5 The emergence of data ecosystems

The shift to the digital age, also leads to a situation in which data has become a key resource. Data is gathered from sensors, consequently stored, processed, analysed and visualised, and is eventually consumed by (human and / or digital) actors to enable them to gain insight and / or make informed decisions (also see the *infological support* abstraction as discussed in section 3.3).

In the digital age, the systems involved in gathering, storing, processing, analysing, and visualising data have evolved to be complex systems themselves, involving different socio-technical actors with their own interests. Data may pertain to the behaviour of humans, thus making it subject to privacy considerations. Data has some correspondence to "something" in the social, economical, or physical world. As such, there is a need to consider the quality of this correspondence, while some actors may have an interest in maliciously changing the data. Data also comes with the question of ownership. Data may be of strategic value to some actors, leading them to want to control the access for others.

As such, these complex systems can be best thought of as data ecosystems involving a complex of human, organisational, and digital actors. Within a data ecosystem, we need to deal with technical concerns regarding reliability, performance, interoperability, semantics, etc, as well as social concerns, such as privacy, trust, ownership, etc.

A data ecosystem can also be regarded as a "data-management enterprise". In other words, a (networked) enterprise with "data-management" as its primary business. Such a "data-management enterprise" will typically be embedded in a larger enterprise, where the latter focuses on a "regular" products / services. The data handled in a data ecosystem can e.g. pertain to:

1. "raw" observations from different sensors / informants,
2. "processed" and / or "enriched" artefacts in terms of e.g. predictive models,
3. digital replicas of real-world phenomenon, nowadays referred to as *digital twins* (Grieves, 2019),
4. representations of "intentions" (e.g. plans, designs, etc), "specifications" (source code, work procedures, etc), or "norms" (regulations, principles, policies, etc).

The development of data ecosystems, as "data-management enterprises", can clearly benefit from the use of enterprise modelling approaches. As such, the above considerations directly apply, while at the same time suggesting the need to more specifically capture data ownership, data lineage, value of data (to specific stakeholders), access control, data regulations, etc.

4 Enterprise modelling goes digital

In this final section, we aim to explore how the transition to the digital age may impact enterprise modelling itself. As enterprise models are increasingly usually represented digitally, and as some of these models are based on digitally represented "evidence" (sensor data, log files, documents, etc), it makes sense to specialise the notion of a data ecosystem to an *enterprise-modelling* data-ecosystem, which manages the data that pertains to / is relevant for enterprise modelling activities.

4.1 Enterprise cartography

In the past, it was already a challenge to keep enterprise models up-to-date. The dynamics of the digital age will only make this harder. Digital technologies can, indeed, be used to support this task. In particular, approaches that use different forms of sensor data (including log files) to infer up-to-date enterprise models, or at least (in)validate existing enterprise models in the light of new evidence. Existing approaches to deal with this challenge, such as software cartography (Krogmann et al., 2009), process mining (Aalst, 2011), and enterprise cartography (Tribolet et al., 2014), may indeed provide a good starting point.

Such approaches would benefit even more, when digital enterprises are actually designing with "mining in mind". In other words, include sensors in the design of the enterprise to enable future mining of process structures, application landscapes, (in)formal business communication, etc, as part of a broader enterprise-modelling data-ecosystem. The latter is, of course, an integral part the broader data ecosystem underlying an enterprise.

4.2 Models as active enterprise knowledge

Increasingly, enterprise models are also used as artefacts in an operational sense. Business process models are used as a specification for business process engine to do its work, business rule specifications / models are similarly used to run rule engines. In the context of software engineering, this has resulted on concepts such as models at runtime (Blair et al., 2009; Vogel et al., 2011). A broader view on this was already provided by (Lillehagen and Krogstie, 2010), who suggest to treat models as ways to capture active knowledge that may support all operational activities in organisations / enterprises. Meanwhile, so-called Hybrid Wiki's (Buckl et al., 2010; Matthes et al., 2011) have also been suggested as a strategy to capture, and operationalise, enterprise knowledge in a semi-structured format.

Digital technologies, in particular in terms of an integrated enterprise-modelling data-ecosystem, will further enable the use of models to capture and utilise enterprise knowledge as part of the operational activities. A specific kind of enterprise models are, of course, models act as complete replicas of part of the enterprise, e.g. enabling detailed simulations. Such models are, nowadays, frequently referred to as *digital twins* (Grieves, 2019).

4.3 Interactive models

As discussed in section 2.4, models quite often act as *boundary object* (Levina and Vaast, 2005) spanning between stakeholders with differing backgrounds. As a consequence, boundary objects a "form" that is engaging to its users, for instance in terms of tangible and / or interactive models. This is where digital technologies potentially have a key role to play.

Research using so-called tangible user interfaces, also indicates that it is possible to more effectively mix the social, digital, and physical actors, to better capture (and discuss) designs (Klemmer et al., 2001; Hornecker and Buur, 2006; Haller et al., 2006; Ras et al., 2012; Maquil et al., 2012). Interactive tabletops have already been shown to support modelling of concepts maps (Oppl and Stary, 2009) or business process models (Rangoni et al., 2014; Fleischmann et al., 2012).

The field of collaboration engineering (Briggs et al., 2006; Vreede et al., 2006) also relies on the use of digital technologies to support the collaborative process, e.g. allowing for anonymous collaborative brainstorming. Something that would be virtually impossible to do in real time using a pen-and-paper based approach.

What still seems to be missing, however, is a better integration of these techniques with traditional enterprise modelling tools. On might even go as far as stating that an integrating architecture is needed for enterprise-modelling data-ecosystem to bring such concepts to fruition.

4.4 Model management

The primary artefact created and manipulated in enterprise modelling activities are, of course, the models themselves. This also implies a need to manage such models well. The need for managing different kind of models arises soon when dealing with complex systems (Barbero et al., 2008), such as, indeed, enterprises. Enterprise modelling, therefore, also involves many different stakeholders, with different cultures, concerns and probably. As a result, there is a crucial need to coordinate those viewpoints together as illustrated in the ISO42010 standard (ISO, 2013) .

Indeed, each viewpoint potentially involves its own modelling language. Anyway, dealing with such a landscape of different viewpoints requires a macroscopic (Barbero et al., 2008) approach to encompass, connect and manage the different viewpoints underlying the different models together. A megamodel (also referred to as a macromodel), as described in Hebig et al., 2012, helps in managing under a single unifying principle, but not necessarily centralized way any modelling elements: the models, supporting language structure (i.e. metamodels), the process (e.g. model transformation) applied to these models. Other relevant information should be added like, e.g., the purpose of the models (Bjeković et al., 2013).

Taking the use of a model into account is also a crucial point in model management. Similarly to the models themselves, the (domain / purpose specific) modelling languages are expected to evolve as well (Bjeković et al., 2014). Modern modelling languages, indeed, support, a certain level of the flexibility (Sottet and Biri, 2016) in order to cope with new situation, reuse in a different context, support uncertainty. History, and evolution traceability is then a necessary property for a proper management. It includes the evolution of the models but also meta-model, semantic annotation, etc. Being able to play past-scenario and ensure coherent update between metamodel and model then become crucial (Silva et al., 2019).

During enterprise modelling activities, new modelling languages / concepts may emerge naturally as well. At the end of the day, a modelling languages are the medium of exchange at the boundary of different proposes. They are collaboratively build by stakeholders for e.g., providing a common understanding of a given problem or sharing viewpoints (Bjeković et al., 2013; Zarwin et al., 2014). Moreover, enterprise stakeholders quite often still prefer the simple use of pen and paper (Malavolta et al., 2012). As a result, languages emerge from structured notation. By being reused and after reaching an agreement between the users, it becomes a purpose specific language (Wouters, 2013).

5 Conclusion

In this chapter, we explored the impact on the transition from the industrial age to the digital age, and the accompanying transition in the economy from a goods-dominant logic to a service-dominant logic, on enterprise modelling. In line with this, the objectives of the chapter were to first reflect on the role of enterprise modelling towards the coordination of enterprise transformations in general, to then explore the resulting challenges posed on enterprise modelling, and finally reflect on how enterprise modelling itself may benefit from the new digital technologies.

We identified the emergence of data ecosystems as a central element in impact on enterprise modelling. Both in terms of the data management of an enterprise in general, as well as the data management pertaining to enterprise modelling.

6 References

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