Digital Enterprise Modelling –

Opportunities and Challenges

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Abstract. Our society is transitioning from the industrial age to the digital age. As a consequence, enterprises need to transform almost continuously, while increasingly becoming "digital enterprises".
During such transformations, coordination among the stakeholders involved is key. Enterprise models, including value models and business ontologies, are traditionally regarded as an effective way to enable such (informed) coordination. At the same time, the digital age also provides ample new challenges to enterprise modelling. Conversely, however, the digital age also provides technological innovations that can support the activities involved in enterprise modelling.
The primary objective of this paper is to (further) raise the discussion related to these challenges.

1 Introduction

Initially, IT enabled enterprises to automate their information processing activities. Soon after, IT also started to be used to steer and control machinery. This enabled us to amplify our human abilities not only in a cognitive sense, but also in a physical sense, resulting in the automation of manual processes, e.g. using computer integrated manufacturing and robotics.

The on-going miniaturisation of hardware, the integration of IT and communication technologies, the networking of IT on a global scale (i.e. the Internet), the advent of mobile computing, and the introduction of different networked sensors / actuators, also enabled us to amplify our communication / dialoguing capabilities as well as (remote) sensing / actuating capabilities.

Recent developments in AI, where traditional symbolical approaches (e.g. *logic* and *rule-based* approaches) have been complemented with statistical approaches. The latter have especially been made possible by the availability of large amounts of (training) data. Combined, these AI approaches have now enabled us to not just amplify our abilities but even to completely take over (and improve on) human roles and activities.

Our society has now, indeed, transitioned from the industrial age to the digital age, where IT has established itself as being an integral part of an enterprise's primary processes, and has quite often become an integral part of their business models as well. Companies such as Amazon, AirBnB, Uber, Netflix, Spotify, Bitcoin, etcetera, provide clear examples of the latter.

As a result of these trends, modern day enterprises are confronted with several challenges. These challenges impact the *design* of these enterprises, from the definitions of products and services offered to their clients, via the business processes that deliver these products and services, and the information systems that support these processes, to the underlying IT infrastructure. These trends drive enterprises to transform continuously, towards *digital enterprises*. From an entrepreneurial perspective, this offers many new possibilities to optimise existing processes and services, while also offering ample opportunities for new product and services.

As discussed in [24], *coordination* among the stakeholders involved is key during such transformations. Enterprise models, and ultimately enterprise modelling languages and associated frameworks, are generally regarded as an effective way to enable such (informed) coordination. At the same time, the digital age also provides ample new challenges to enterprise modelling, and value modelling and business ontologies in particular. Conversely, the digital age also provides technological innovations that can actually support the activities involved in enterprise modelling.

The primary objective of this paper is to (further) raise the discussion related to these challenges. In line with this, the paper covers three more specific aims. The first aim (addressed in section 2) is to reflect on the role of enterprise modelling towards the coordination of enterprise transformations in general. The second aim (addressed in section 3) is to explore the challenges, which digital transformations pose to enterprise modelling. The third, and final, aim (addressed in section 4) is to reflect on how enterprise modelling itself may benefit from the new digital technologies.

2 The Role of Enterprise Models

Scholars across different forms of domain modelling (including systems modelling, knowledge modelling, information modelling, enterprise modelling, and software modelling) have provided definitions of the concept of model.[3] Most of these definitions are based on the well-known *semiotic triangle* [19] (see figure 1).

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 [18, 28]. Based on this linguistic background, the semiotic triangle has also been used, directly or indirectly, by several scholars[3] to reason about the foundations of (information) systems modelling.

In line with the semiotic triangle, we [2] define a model as "*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 world.

[3] This paper certainly does not aim to provide a literature review on the concept of model. In earlier work, as reported in e.g. [2], we did aim to provide such an overview.

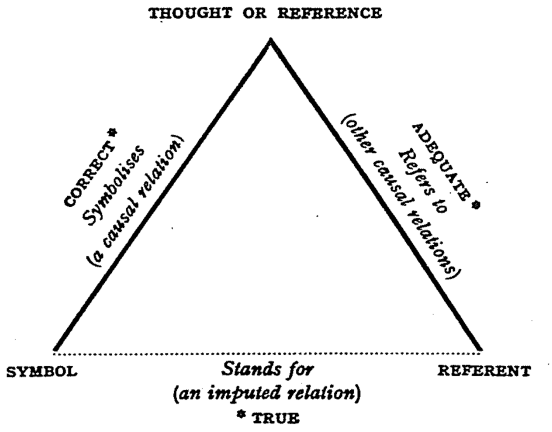

Fig. 1. Ogden and Richard's semiotic triangle [19]

During any enterprise transformation, *coordination* among the key stakeholders and the projects / activities that drive the transformations is key [24]. Enterprise models are generally considered as an effective way to support such coordination, as such 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, many, languages and frameworks have indeed been suggested as a way to create and capture a different enterprise models.

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

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 [23]. Furthermore, since 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 [20]).

3 Digital-Enterprise Modelling

In this section we aim to explore some of the challenges which the transition to the digital age potentially poses to enterprise modelling.

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 leads to a situation in which these enterprises need to work hard to keep their business models up-to-date and viable [22]. As a result, modern day enterprises need to be more agile than ever.

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). This may sound as a potential threat to enterprise modelling. Nevertheless, enterprise modelling as such is a mere neutral means to an end with a clear (intended) Return on Modelling Effort.

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,[4] 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 factor, which define 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 [24].

The tension between the (agile) needs of 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 [10] to express the overall *direction of change*, rather than the more detailed boxes-and-lines diagrams such as ArchiMate [12] models. At the same time, the latter type of models are a prerequisite to conduct a detailed impact analysis, or a thorough GDPR compliance check. As such, the overall purposes as identified in section 2 will likely lead to the use

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

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

3.2 Modelling concepts 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 [8], we already explored some of the consequences this may have on enterprise modelling languages such as ArchiMate. Here, we take a broader view on this topic, by not limiting ourselves on the possible impact of a specific modelling language. In doing so, 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 [22] focus on value exchange between economic actors in a traditional supplier and consumer role. Value network modelling techniques, such as e3Value [9], 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 [6], thus leading to a need for new / different modelling concepts [26]. Value network modelling techniques, such as e3Value [9], 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 [17] the authors report on what the possible impact of blockchain on business process management can be. More generally, as argued in [8] 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). However, this does require these models to capture the relevant aspects of an enterprise, thus requiring modelling concepts able to express this. For example, in the context of the GDPR, this may include aspects such as the location where data is stored, where it is processed, where / how it is gathered, etc.

As argued in [8], 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) specialisation layers.

4 Digital Enterprise-Modelling

In this section, we aim to explore how the transition to the digital age may impact enterprise modelling itself. Needless to say that we can only explore some of the opportunities.

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 [11], process mining [1], and the more general notion of enterprise cartography [27], may indeed provide a good starting point. These 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.

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 in concepts such as models at runtime [3].

A broader view on this was already provided by [14], who suggested to treat models as ways to capture active knowledge that may support all operational activities in organisations / enterprises. Additionally, so-called Hybrid Wiki's [5, 16] 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*.

4.3 Interactive models

Models are quite often used in a context in which the need to span the "boundaries" between different groups of stakeholders with differing backgrounds and interests, as such turning them into so-called *boundary objects* [13]. 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 role to play.

For instance, research involging the use of so-called tangible user interfaces, indicates that it is possible to more effectively mix social, digital, and physical actors, to better capture (and discuss) designs [25, 15]. Interactive tabletops have already been shown to support modelling of concepts maps [21] or business process models [7].

The field of collaboration engineering [4] 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.

5 Conclusion

In this paper, we explored the impact on the transition to the digital age on enterprise modelling. In line with this, we reflected on the role of enterprise modelling towards the coordination of enterprise transformations in general. We then explored some of the challenges which the shift to "digital enterprises" puts on enterprise modelling, while finally also reflecting on how enterprise modelling itself may benefit from the new digital technologies.

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