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Enterprise Architectures for Supporting the Adoption of Big Data

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ABSTRACT

Governments from all over the world are struggling to take advantage of big data developments. Enterprise Architecture (EA) can be used as an instrument to integrate big data (BD) in the existing business processes and ICT-landscape. In this policy paper, we explore the role of EA in the adoption of BD. For this, we adopted a qualitative case study approach and investigated a large administrative organization that was in the process of adopting BD. We found in our case study that the first attempts were focused on integrating big data in the current landscape, but this encountered too many challenges that halt progress. To overcome the challenges, a separate BD department and accompanying infrastructure was created. The strategy was first to reap the benefits of BD and to understand what should be done, and thereafter integrating the working systems in the existing landscape. The findings suggest that current infrastructures might not be suitable for integrating BD and substantial changes are needed first. In the case the role of BD needed to be first clarified before EA could play a role in adopting BD. EA should deal with the uncertainties and complexities by ensuring a configurable landscape, by providing an incremental approach for adapting the infrastructure step-by-step, before the benefits of big data can be gained. Developing an incremental migration plan was found to be a key aspect for the adoption of BD.

CCS Concepts

• Applied computing➡Computers in other domains • Computing in government➡E-government.

Keywords

e-government, enterprise architecture, ICT-architecture, big data, BOLD, open data, infrastructure

1. INTRODUCTION

Despite its significance, limited attention has been given to the big data (BD) and the possible roles enterprise architectures can play in helping organizations to adopt BD. Enterprise Architecture (EA) is "*a coherent whole of principles, methods, and models that are used in the design and realisation of an enterprise's organisational structure, business processes, information systems, and infrastructure*" [1] (p.3). EA can improve sharing and integration of IT resources across the enterprise [2], create and enable interoperability, guide design of new infrastructures and enable transformation [3]. It is therefore allowing organizations for proactively and responding to disruptive innovations by identifying and analyzing the execution of change toward desired business vision and outcomes [4]. EA can be used to integrate new developments in the existing organizations, such as clouds, bring your own device (BYOD), and also BD. Yet there is scant attention given to the role of EA in BD adoption.

Big data is about collecting and processing large volumes of data from a variety of sources [5]. BD has been recognized as becoming an essential capability for administrative organizations. Most public organizations are information intensive by nature and the analysis of the data can provide new insights. For example, tapping into these vast amount of data provides the potential to improve activities of public organizations like inspection [6]. BD commonly refers to big amount of data that often are also big and high in variety and velocity, which makes them difficult to handle using traditional tools and techniques [7]. This suggest that EA should help to adopt and integrate these new tools and techniques in the existing landscape. BD is often characterized with three or more Vs, including Volume, Velocity, Variety [8]. Gandomi and Haider [9] add three other Vs to this list; Value, Variability and Veracity. These Vs show how BD is different from traditional data and need new ways of dealing with them.

Adopting and applying BD technologies is great challenge for organizations, because possible applications are unclear, there is a lack of expertise, the tools and techniques that can be used for BD are not clear and need to be selected, and the potential impact of BD is hardly predicted. BD technologies might need to be adjusted to their application areas and the infrastructure of organizations must be able to support the use of new technologies. EA should help to understand the potentials of these new tools and technology trends, and help designing better business processes and suitable infrastructures for BD handling [10]. The objective of this paper is to analyze the role of EA in the adoption of BD initiatives in public organizations.

The paper is structured as follows. In Section 2 we briefly discuss the background of BD and EA. Thereafter, the research method is explained in Section 3. In Section 4 we present overview of the case study. In Section 5, we discuss the case study findings and their policy implications. Section 6 contains the conclusion.

2. BACKGROUND

Traditionally, organizations used well-structured data that is collected for a certain purpose and stored often in relational databases. Basic queries can be asked based on this data. Nowadays, BD development extends their concerns of key data which is different, not collected for a certain purpose and stored in different ways and formats. BD enables organizations to go beyond just utilizing each database and data set in isolation. Data sets are combined or integrated to achieve new insight.

The integration of new technologies in organizations is often found to be difficult, as processes and technology is not flexible enough to support the extraction of data from databases, processing the information and using data analytics for drawing conclusions form the data. In the current climate policy-makers and decision-makers see the potential of big data technology, however, realizing these benefits is much more difficult. BD can be used to increase citizen engagement in public affairs, prevent fraud and crime, improve national security, and support the well-being of people through better education and health care [11]. The promises are high and policy-makers are looking for ways to integrate big data in their EAs.

EA captures a range of aspects including business processes, data models, applications and technical infrastructure [12]. Usually EA consists of descriptive and prescriptive models to understand what the current situation is and what the desired situation should look like [13]. The architecture models should help to improve (parts of the) organization (i.e. the business process, data, application and infrastructure) and take into account the relationships as depicted by the architecture. In this way a coherent picture is created. This approach assumes that the desired situation can be blueprinted to some extent and that the relationship with the current situation is clear. Another view on EA is as a process in which the focus is on managing the improvement process which is supported by architectural instruments [14].

EA can be used for developing commonly understandable interpretations of existing and new technologies, so it could be used as a tool for organizations to understand the potential and feasibility of new technologies [15]. In the BD movement, EA is expected to be impacted and evolves continuously, but how to use EA to facilitate effective access and analysis of very large and heterogeneous datasets in real-time is still an open question [16]. This paper attempts to explore this question by firstly address the role of EA in BD adoption.

3. RESEARCH APPROACH

Although there is much work on BD and also on EA, there is limited work combing these fields. This policy papers tries to get more grip on how EA can be used to integrate BD efforts in organizations. For this a case study of a large administrative organization was analyzed. The case study research methodology is particularly well-suited to IS research, since the object of the discipline is the study of IS in organizations, and the 'interest is shifted to organizational rather than technical issues' [17]. Case study enables to study a phenomenon in its naturel setting [18].

In the case the background and the attempts to introduce of BD is described. The case contains path dependencies, referring to taking into account past decisions and the procedures and routines involved. These path dependencies are essential for understanding the case, but limits its generalizability.

The BD implementation efforts were analyzed over time by conducting interviews and analyzing documents capturing the history. Three interviews were used in which interviewees were at the management level (administrative department, enterprise architect and competence center manager). Although a single case study of a specific organizations might not be representative for other organizations, this explorative case study helped us to gain insight into how BD was adopted in governments.

4. CASE STUDY BACKGROUND

The Dutch Tax organization has a legal basis to use data to improve the assessment of tax filing and collection of taxes. The tax organization has a separate department which maintains their architectures. For architecture modelling, the Open Group ArchiMate standards has been adopted and detailed models has been developed. Formal documentation is made on many aspects of the architecture. This enables the managing of the architecture and the migrations towards new situations. Also architecture principles are maintained.

The Tax organization has initiated various BD programs to improve their administrative processes. They have high ambitions in reducing the number of staff by utilizing BD analytics to detect tax evasion and fraud. Their strategy is to avoid the developed of new and risky large systems and their focus is on creating a coherent landscape in which data can be exchanged. Data is stored in various places in the organization, and external data sources are in use.

The organizations started various initiatives in the field of BD in a bottom-up manner. As manual control on every tax filing has become impossible, the idea was that BD enables a risk-based approach in which existing data is used to create risk profiles. Various departments were starting to make better use of their data. Most departments educated some of their current staff to understand and analyze the data, whereas other departments hired a specialist in this area. Although this resulted in progress, the efforts proved not to be effective given the high ambitions of the management. The latter wanted to progress faster.

An interviewee stated that "departments should work together to avoid duplication of efforts and high costs. Only when they work together data quality and reliability can be accomplished at acceptable costs". To progress faster without being constraint by the existing institutionalized patterns and procedures, a new organizational entity was founded. This department was operated separately from all the other departments, and directly led by the management board. In this department, experts were hired who had a proven record of using BD in other domains. This

department collected the data by extracting them from the existing systems within the Tax organization and importing them in their own systems. Also external sources, like social media, were used to enrich the data. For example to detect trading activities that were not reported. Thereafter analysis was made without being bounded by the organizational structures. The use of their own systems irrespective of the current architecture and standard resulted in quick development, but also in more heterogeneity.

By teaming up with tax experts and others a kind of agile development teams were created. This allowed for conducting analysis and getting fast feedback. The finding of the data proved to be a cumbersome process. The data has various qualities which makes it sometimes hard to use. Also understanding the domain was found to be a condition for being able to interpret the data.

5. FINDINGS AND POLICY IMPLICATIONS

5.1 Technology determinism

In the case study, the developments of using technology are driven by a kind of 'management-by-magazine' in which all kinds of benefits and promises are made about the potential of BD. Which types of applications and how these promises can materialize is largely unknown. A kind of technology deterministic view seems to be taken, which does not take into account that the organization needs to adapt as well. The statement 'data is the new gold' was embraced. In this view, BD technology should be used and will bring the benefits once implemented. One interviewee mentioned that "a large software application was bought for this purpose, without prior considering the impact on the people, business processes and organizations. We wanted to know what was possible". In technology determinism, technology is viewed as the key mover of change [19]. In contrast, the case shows that BD technology can be adopted in various ways. It can be used to empower staff, but also to replace staff. Social factors play a major role in its development and adoption.

Structuration theory argues that human agents draw on social structures in their actions, and at the same time these actions serve to produce and reproduce social structure [20]. The evolution of new applications is a process of social interaction between multiple agents (Allen, 2003). The duality of technology of Orlikowski (1992) describes technology as assuming structural properties whilst being the product of human action. Technology is physically constructed by actors in a social context, and socially constructed by actors through the different meanings they attach to it. The structures can both enable and constrain development and change [21, 22].

The technology determinism thinking held by the top management resulted in a neglect of the existing and evolving social-technical structure which is documented by EA. EA was expected to inform management about the roles and tasks held by different departments, applications and infrastructure supporting them. Structuration theory draws the attention to the need for social aspects evolving with technical aspects. The lack of EA in BD decision-making reflects on the difficulty in using EA to integrate BD development in the organization.

5.2 Implementation challenges

The assumption that the desired situation can be blueprinted sufficiently to integrate BD was not to be found valid in our case. The complexities were found at different levels which proved to be too complicated to develop a blueprint in which BD was integrated in the existing structure. The infrastructure was not able to handle the large amount of data, data proved not to be interoperable and people do not have the skills and expertise for doing this. These issues needed to be resolved and understood before a blueprint can be made to integrate BD use in the current infrastructure. Furthermore, we found the following key challenges in the implementation of BD applications.

- *Flexibility*: Inability to adapt the current infrastructure and software to allow for the access of required data or the utilization of BD.
- *Interoperability*: Lack of interoperability between the data. Data could not easily processed and connected with other data to facilitate analysis.
- *Collaboration:* A lack of collaboration among different roles and processes hindered the collection of data. There was friction between the departments in charge of the collecting of the data and the persons who wanted to conducting data analytics.

All these challenges resulted in difficulty to integrate the BD in the current IT-landscape. Over time a different approach was taken and data was extracted from database and a separated system was created to make progress.

5.3 Developing new capabilities

BD requires new capabilities that are not readily available in the organization. Developing the new capabilities requires that "staff should be able to program, analyze the data, have knowledge of statistics and being a good communicator". These capabilities can either be developed in house by training and experimenting or can be bought on the market and thereafter internalized. Teece et al. [23] define dynamic capabilities as "the ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments" (p. 516), whereas Eisenhardt and Martin [24] define dynamic capabilities as "the organizational strategic routines by which firms achieve new resources configurations as markets emerge, collide, split, evolve and die' (p. 1107).

A main challenge was to develop a new set of capabilities that was not in possession before. These capabilities (see Table 1) range from the organizational to the technical level. This makes it not easy to realize the benefits of BD. In particular the many changes that were needed could not be dealt with by the organization. Their absorptive capacity was not sufficient to deal with all these changes at the same time.

Table 1: overview of new capabilities

Category	Capabilities needed
Technology	• Having a basic infrastructure for sharing BD • Having standards for BD exchange • Using Data analytics software for analyzing BD

Collaboration	• Create a collaboration network to gain access to data • BD value creation processes • BD governance
Strategy	• Understanding of BD opportunities for the organization • Top management support

To overcome the challenges of flexibility and interoperability, the organization is required to fundamentally improve its infrastructure and software technology. In the case study, the current EA documents informed BD developers about the location and content of data, but this was found to provide limited help in integrating BD into the existing infrastructure and software.

To improve collaboration, the value creation process of BD should be negotiated and designed in a collaboration network for allowing further accessing and usage of data. Data governance that ensures the quality of data and the appropriate use of data is important in sharping and maintaining a social structure suitable for BD development. This goes beyond the current use of EA in documenting who is doing what in a business process.

Finally, leadership support is essential in BD implementation. This means the top management is able to understand and can make decisions-based on freeing resources and support the use of BD from a global and long-term perspective.

Possessing the above capabilities allows the organization to reconsider the role of EA in BD implementation. The case study implicates that given sufficient capabilities EA could play a more important roles in BD implementation. This will be discussed in the next section.

5.4 The roles of enterprise architecture

In the initial approach, the idea was to facilitate bottom-up initiatives and to gradually incorporate the results of the initiatives in the EA. The bottom-up initiatives were expected to develop software components and introduce the creation of new processes and procedures for dealing with BD. However, the initiatives turned out to be too diverse and did not create cross-departmental applications. They were proven not advanced enough to provide undisputed input in the EA. The existing departments did not have the capabilities to make use of this advanced technology. Also it was unclear how existing systems should be updated and data governance should be dealt with.

This resulted in the creation of a separated department. BD experts were hired and used to create this department. New technology was used, which was different from the conventional technologies used. This effort came with the creation of added value applications, like dynamic monitoring of economic activities of persons and organizations who did not pay their taxes. However, this also resulted in the creation of a separate architecture domain which could not be integrated with the existing architecture.

EA plays a role in various ways as summarized in Table 2. On the left-hand side, the possible roles of EA are outlines based on the literature shown in the column at the middle. On the right hand side the role in the case study is summarized. The table shows clearly that multiple roles of EA were important. Only client orientation and decision-making support were not found to

be important in the case study. Although BD helps to better understand clients, EA was not used to enable this. Also the decision to use BD was already made, and EA was not used to support this decisions.

Table 2: overview of contributions of EA

Role of Enterprise Architecture	Literature	Findings in the case study
Dealing with complexity	[25-28]	The ability to decompose big data effort in manageable parts was a key aspect
Facilitating re-use	[3, 28-30]	Identification and development of reusable building blocks for collecting and processing big data
Enabling interoperability	[31, 32]	Interoperability was perceived as a long-term problem. At the start manual activities were performed to enable transferring data to and from systems
Client-orientation	[3, 33]	Not identified
Creating flexibility	[30, 34, 35]	The crating of a configurable software and data infrastructure needed to facilitate a varitye of BD applications
Communication	[27, 28, 36] [37]	The involvement of the administrative staff to have an understanding of the implications
Impact evaluation	[26, 36, 38]	To evaluate the impact of the change of the infrastructure and to take measures to deal with them
Decision-making support	[39-42]	Not identified
Migration strategy	[3, 40]	This was found to deal with the limited absorptive capacity and ensure an incremental adaptation

With the identified roles of EA in the case study, whether the contribution of a certain EA role can be maximized relies on the way of using EA. The case study reflects two approaches: architecture as blueprint and architecture as process.

5.5 Architecture as blueprint and process

The BD efforts were largely pushed by the board, which gave limited space to the architecture department. BD phenomenon was

surrounded by uncertainties which makes it hard to use the architecture models for determining its impact. Instead, an "experimenting and learning by doing" approach was adopted. This *process* approach enabled the creation of some applications by department and showed the possibilities of BD. It resulted in higher costs due to the fragmentation of initiatives and control and maintenance problems, as software and data quality were hard to manage. One interviewee commented that "wrong data could spread as an oil slick in the organization. Data stewardships and ability to manage data is needed.

Although the models are hardly used for understanding the implications, the models did provide an overview of the data sources. One interviewee stressed the importance of EA "Data should be given only once to the government. EA should ensure that the departments reuse the data" The expectations is that once it becomes clear what BD is and how it can be used, there will be a larger role for the architecture models. In particular, the models can be used for impact analysis and prescribing the desired infrastructure. Given the many uncertainties and lack of understanding on how BD should look like and how the existing landscape should be adapted, EA was hardly used for BD adoption.

The existing architecture was not ready for BD. A move from 'built to last' to 'built to change' was necessary according to the interviewees. System quality was not sufficient, as data could not be easily abstracted, systems were not flexible enough and new functionality could not be integrated in the existing architecture. The adoption and use of BD requires that the existing systems are prepared for this. The manager of the architecture department stated that "EA should enable the reconfiguring of the applications and data for different purposes". In the case study, however, each time a new system was created. As such an incremental strategy was followed. This approach emphasizes the roles of EA in dealing with complexity, integrating new systems in the landscape, facilitating reuse and communication.

Defining the starting points of BD initiatives is a difficult endeavor. The strategy of trying to integrate BD into the current architecture provided to be not working, and therefore, an approach was taken by developing the efforts independent of the organization and to integrate it at a later stage. Nevertheless, the data should be collected from the existing organizations and a kind of agile approach was taken by involving policy-makers, administrators, domain (tax), and BD quality and analytics experts. These teams developed the ideas for the applications, collected the data and processed the data for creating new insight. These multidisciplinary teams contained people form the current department and the newly founded BD department.

The organization under study facilitated bottom-up initiatives. Although this stimulated the development of new applications and the use of big data, this resulted in a fragmentation and encountered many problems and generated limited value creation of BD. In particular, the departments only analyzed their own data without looking at the possibilities to use data of other departments, which limited the value that could be created. Although the bottom-up initiatives were instrumental to the acceptance of the use of BD, it created also difficulties for the separated BD department. They were sometimes seen as not necessary and using different technologies. In the long run this created integration problems.

6. CONCLUSIONS

Policy-makers and decision-makers are jumping on the bandwagon to adopt BD. Driven by 'management by magazine' they require their departments to initiate the adoption of BD. Yet often a clear vision on what can be accomplished and how BD should be adopted is missing. Our case study shows that the adoption of BD is not easy, as it encounters many challenges and new capabilities are required that might not be available within the organization. Given the uncertainty about possible applications and capabilities needed, initially a bottom-up approach was taken to adopt BD, however, this approach did not work out. Although this approach helped to get an understanding of BD and its potential for the organizations, the departments were not able to develop the capabilities needed and the approach resulted in heterogeneity; the infrastructure could not be adapted, data quality could not be ensured and using this approach the advantage of BD were not realized. Thereafter, an alternative adoption strategy was followed by creating a separate department. This department has the power and capabilities needed and did not suffer from path dependencies, to make use of big data in a quick way. In this way facilities were created at lower costs and data quality could be ensured. Although this was instrumental to creating BD applications, this adoption approach did not facilitate the adoption of BD in the running organization. This requires a step that needs to be done in the future.

The creation of a flexibility, configurable software and data infrastructure, ensuring data interoperability and enhancing collaboration among departments were found as key challenges. The role of EA was found in various areas, but its effective use seems to be limited at the early stages. Initially, EA was primarily used to provide an overview of the various data sources. Only after it was clear how BD could be implemented and used by the organization, EA start playing an important role in the creating of a flexible and configure infrastructure and the assessment of BD applications. This shows the need to develop EA in such a way that it is able to deal with the typical characteristics of BD.

The case study reflects two different approaches of using EA in BD adoption: a process and blueprint approach. Although the architecture as process approach allow for faster achievement of BD benefits, it does not take into account the installed base of systems and might create integration problems in the long run. In contrast, the architecture as blueprint approach seeks for long-term benefits of BD implementation, but it assumes that the future situations are known and can be outlined in advance, needs the development of dynamic capabilities, and has less ability to deal with the uncertainty surrounding future development. Both approaches seem to have its pros and cons and we recommend to compare the approaches in further research. Having more case studies can provide deeper insight on EA's support for BD implementation in governments. The development of EA implementation patterns that are suitable for administrative organizations to adopt BD technologies will benefit the sector and BD practices.

Acknowledgement

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