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BIG DATA MANAGEMENT: RELATIONAL FRAMEWORK

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ABSTRACT

Volumes of available digital data have been significantly expanding over the past decade. Alongside the volume, diversity and complexity of digital data have also been growing. Contemporary devices and systems are capable of generating data vastly exceeding capabilities of organizations and conventional information technologies to process it. Big, diverse and complex data presents novel challenges for organizations—but also opportunities. Big data enables tackling longstanding complex problems that would otherwise be out of reach. It also opens new scientific and commercial possibilities that could not exist without availability of data. Organizations utilizing large volumes of diverse data, however, face unique challenges. The challenges range from technological and processing issues to business and management matters. Organizations need to adopt appropriate management strategy in order to satisfactorily deal with the issues arising from utilization of big data. This necessitates understanding of relationships between the aspects of data and their managerial consequences. We examine the essential characteristics of big data and explore pertinent managerial implications.

JEL: C8, C81, C82, C88, D7, D8, D81, M15

KEYWORDS: Big Data, Data Aspects, Processing Capabilities, Strategy, Actionable Knowledge, Information Technology Management, Management of Information Systems

INTRODUCTION

Organizations rely on a broad range of information and communication technologies. Large number of organizations would be unable to function without the computer and information technologies (Turban and Volonino, 2011). Information technologies play a prominent role in many knowledge-intensive organizations. They are often designated as the core assets (Alvesson, 2004). Knowledge workers largely depend on information systems and services deployed in organizations (Davenport, 2005). Essential business processes are implemented within internal information systems. Formerly pen-and-paper business processes have been transferred into electronic business processes. This transformation facilitates enhanced working efficiency and productivity. It also permits task automation and improves accessibility of information and resources (Wikoff, 2008).

Individual organizations pursued their own paths when adopting information technologies. There are, however, noticeable adoption patterns. Initially, organizations had separate strategies for building information technology infrastructures and capabilities. Dedicated information technology departments have been relatively absent. Shortage of trained professionals and insufficient experience with information technologies have been prevailing. There has been also notable lack of best practices. This has led to uncoordinated long-term strategy and planning (Butler and Murphy, 2007). Separate departments in organizations have been implementing their specific information infrastructures and systems (Papastathopoulou et al., 2007).

Strategic coordination, planning and deployment of information technologies have become desirable (Georgantzas and Katsamakas, 2010; Boar, 2000). Smooth transition to novel management of information technologies has been favored. Radical reengineering of deployed systems would be costly and could hinder operations in organizations. Hence, solutions that could effectively utilize existing technologies have been preferred. A viable solution, in a form of organizational portal, has been presented to address these issues (Collins, 2000).

The portals provide a single-point access to distributed systems and services in organizations (Oertel et al., 2010; Sullivan, 2004). They do not represent a radically new technology, but rather a beneficial merger of readily available technologies. Enabling technologies have been the standardized communication protocols, web specifications, and service-oriented architecture and design (Rosen et al., 2008). Portals feature web-based front-ends and database plus legacy technologies at back-ends. The interoperability between front-ends and back-ends is facilitated by service-oriented technologies. Deployment of portals effectively marked internalization of web-based technologies by organizations. Internet and World Wide Web have become external economic drivers. Generation and flow of digital data have been rapidly expanding. Data collection and utilization technologies have emerged—initially, as web data analytics utilizing data acquisition capabilities of web servers (Kaushik, 2009).

Internet and web technologies have allowed global interconnectivity and access of resources (Knight, 1998). Many resources have been digitalized. Digitalization of the formerly analog resources and media has been one of the first waves of digital data expansion. Another wave has brought forward a vast content produced by organizations and individuals (Krumm et al., 2008). Broad spectrum of content has notably contributed to diversity of digital data. Expanding content and services on the World Wide Web have attracted large numbers of users. Businesses have started tracking users and analyzing data about their interactions (Lackner et al., 2010). Data analysis has proven to provide suitable insights on system functions and users' interactions (Géczy et al., 2007 and 2008). This has fueled development in analytic and data acquisition technologies. The technologies extended to specialized hardware and software tools. However, the data growth significantly outpaced capabilities of systems to process it. And soon, big data problems have emerged.Due to novelty of big data issues, there is a scarcity of available studies addressing pertinent management issues. This work attempts to fill the gap by presenting a relational framework for managing big data challenges. The relational framework explores aspects of data and related management issues. It highlights several core managerial domains.

The manuscript is organized as follows. The literature review section is followed by the 'Big Data Problem Approach' section. It presents the relational perspective on challenges associated with big data. The next section, 'Relational Management Framework', introduces novel management framework for addressing big data challenges. Several high priority managerial domains are identified and concisely discussed. The presentation concludes with a concise summary of the essential points.

LITERATURE REVIEW

Data has become a currency of the information economy (St. Amant and Ulijn, 2009). Economic activities have been gradually evolving from production of goods, throughout provision of services, to extraction of value from information and data. Services have become the dominant economic activity of contemporary developed economies (Bryson et al., 2004). Information technologies and services have been rapidly expanding and gaining ground. Values of data and information have been rising and organizations have been realizing it (Lievesley et al., 1993). Extracting valuable information from data has become the target for increasing number of organizations. They have started collecting growing volumes of data and exploring various monetization opportunities. Data sales have become a viable revenue stream. However, organizations have been exploring further prospects not only in selling data, but also in analyzing it with the aim of improving their own operations.

Organizations have been strengthening their data collecting and processing capabilities (Davenport et al., 2007 and 2010). Expansion of data acquisition operations has led to rapid growth of data. Large data volumes demand significant computing power for processing. They also demand significant increases in storage capacity. Growing demands for processing, storage and management of big data have led to development of scalable and distributed technologies (Frischbier and Petrov, 2010). Hence, novel challenges have emerged—big data problems (Buhl et al, 2013; Hunter, 2013). Big data problems have arisen from the disproportionate growth between collected data and capabilities of organizations to process and manage it (Klein et al., 2013; Walsh et al., 2012). Data has been growing considerably faster than advances in processing technologies. Data volume has become just one of the growing number of factors affecting processing. Other factors, such as diversity and structure of data have also started significantly affect processing. Various aspects of big data have presented notable challenges.

Suitable deployments of analytic methods have become an important aspect influencing data acquisition, processing and management (Bernhardt, 2004). Numerous analytic methods have been developed and applied to meet the growing processing demands. Analytic methods and tools have become highly regarded for their capabilities to extract valuable information and actionable knowledge from data. The critics of big data and analytics argue that big data and its analysis without the context are inadequate. This argument has gained strength with the major failure of Google Flu Trends project (Lazer et al., 2014). The project has been considered a prime example of big data power—as a more useful indicator of flu than government statistics. However, it completely missed the largest swine flu pandemic.

Big Data Problem Approach

The big data problem has emerged relatively recently in organizations (Buhl et al, 2013; Hunter, 2013; Klein et al., 2013; Walsh et al., 2012). Digital revolution and information technologies have brought numerous benefits, but they also provided fertile grounds for emergence of big data issues. There are four factors notably contributing to big data problems: digitization of business processes and accompanying data, accumulation of extra data, extraction of actionable knowledge from data, and monetization of data.

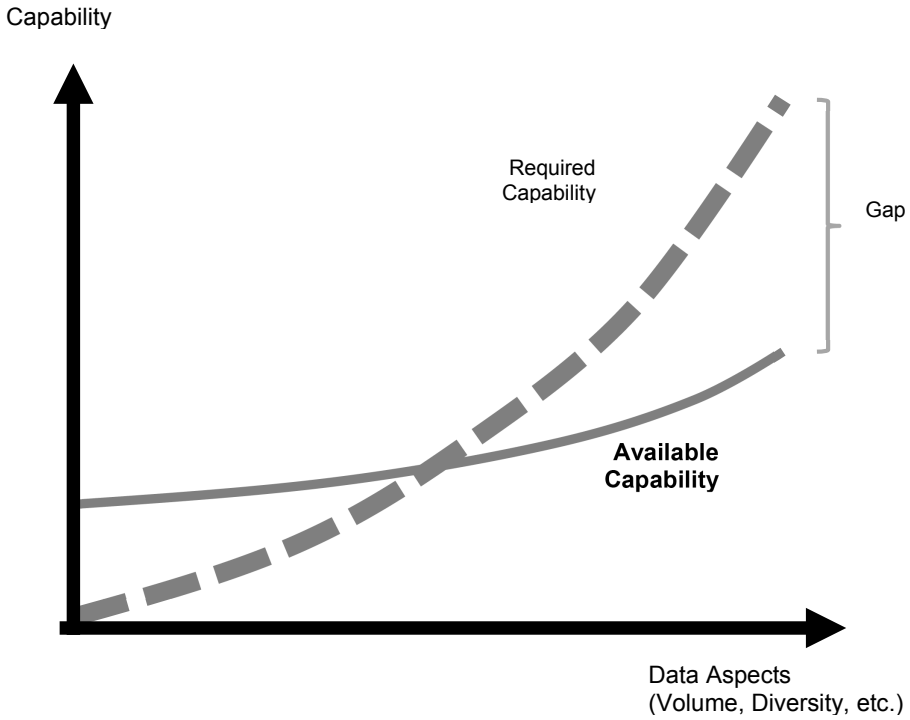
Digitization of business processes facilitated the transfer of formerly paper-based processes into computer oriented business processes, environments and platforms. Business processes have been reengineered to fit into organizational internal digital environments. Related business process data has also been digitized (Oertel et al., 2010). Digitization of business processes and data have accelerated innovation and enabled several levels of automation of business processes (Beydoun, 2013). It has enhanced operating efficiency of organizations. However, it also made organizations dependent on information technologies.

Acquisition of extra data by organizations has been progressing in conjunction with digitization of business processes. Acquired additional operational data has various beneficial uses (Géczy at al., 2011). For instance, technologies for collecting data about users' interactions with the digital environments have been implemented. Such data has enabled efficient usability monitoring of business processes and services. It improved targeting and planning of innovations of business processes, services and organizational portals. Organizations have been implementing various data collection technologies and acquiring growing volumes of data. Large volumes of operational data can be explored for gaining insights into functioning of organizations. Analytics have been deployed to discover opportunities for increasing operational efficiency and innovating business processes. Data analytics have also been employed to gain competitive advantage for organizations (Davenport et al., 2007 and 2010). Actionable knowledge extraction methods have been utilized for improving core competencies (Laursen and Thorlund, 2010). Extensive data acquired by organizations can be monetized. Organizations have been monetizing the data by selling it to external parties. This way, organizations have been establishing additional revenue streams. Some data can be sold directly with little or no extra processing. However, majority of the data requires processing before it is

sold. Sale oriented data processing largely consists of removing sensitive elements and then formatting remaining data to standardized or agreed-upon style.

Collection and processing of large data volumes by organizations have led to various challenges (Wigan and Clarke, 2013; Buhl et al, 2013; Klein et al., 2013; Hunter, 2013; Walsh et al., 2012). These challenges are commonly referred to as big data problems. Big data problems do not refer only to the issues originating from the size of data. Such perception has been propagated by information technology providers doing business in 'big data'. Understandably, it serves their marketing and business purposes. However, this would be a rather narrow perspective on big data challenges.

Figure 1: Illustration of the Relational Perspective on Big Data Problem in Organizations



Bigger data requires greater processing capabilities. Growing aspects of data, such as volume and diversity, necessitate growing storage requirements and computing power to process it. Demands on processing capabilities rise faster than various aspects of data. The problem of big data emerges from increasing gap between the available capabilities to process acquired data and the required capabilities given the existing processing methods.

We approach the big data problem from an enveloping perspective. The presented relational approach explores relationships between various aspects of data and its handling. In this way, the size of data is only one of the aspects. Significant advantage of the relational approach is that it is both encompassing and illuminating. It highlights interrelationships between the aspects of data and its management. The emergence of big data problems, from the relational viewpoint, is illustrated in Figure 1. Horizontal axis represents various aspects of data, such as diversity, volume, quality, etc. Vertical axis represents capabilities to manage the data and related issues; such as storage capabilities and processing power. The big data problem is expressed as a gap between required capabilities to manage data and organization's available capabilities. Presenting the big data problem as a relationship between the various aspects of data and capabilities to manage it has several benefits. It allows clear distinctions between data aspects and required management capabilities. Furthermore, it permits observations of relationships between various aspects of data and required capabilities to manage such data. This approach allows in-depth elucidation of both data and management aspects.

Organizations can focus on the specific issues related to their data and its management. They can accurately evaluate features in the respective domains. Relationships highlight the links between the aspects of data and its management requirements. This allows observing various effects between interconnected aspects. It enables managers to elucidate how changes in specific aspects of data affect management requirements. Working from such encompassing framework enables organizations to accurately model and optimize deployment of their resources. It also facilitates innovation and planning in both short and long terms.

Relational Management Framework

Relational perspective on the big data problem encompasses both data aspects and management domains. Collection, processing and retention of large data volumes present novel managerial challenges for organizations (Tallon, 2013). The challenges demand adoptions of new management approaches that may significantly depart from the methods organizations have been using (Malik, 2013). Transition to new management framework should proceed in a timely manner. Embracing new management methods brings forth transitional issues (Hamel, 2007). While it is desirable to transition as smoothly as possible, there are both expected and unexpected issues in any transition. Many issues can be managed by deploying information technology solutions supporting managerial and transitional aspects. However, such technologies require significant investments. While larger organizations can afford greater investments and faster adoption, smaller organizations may decide to transition more slowly.

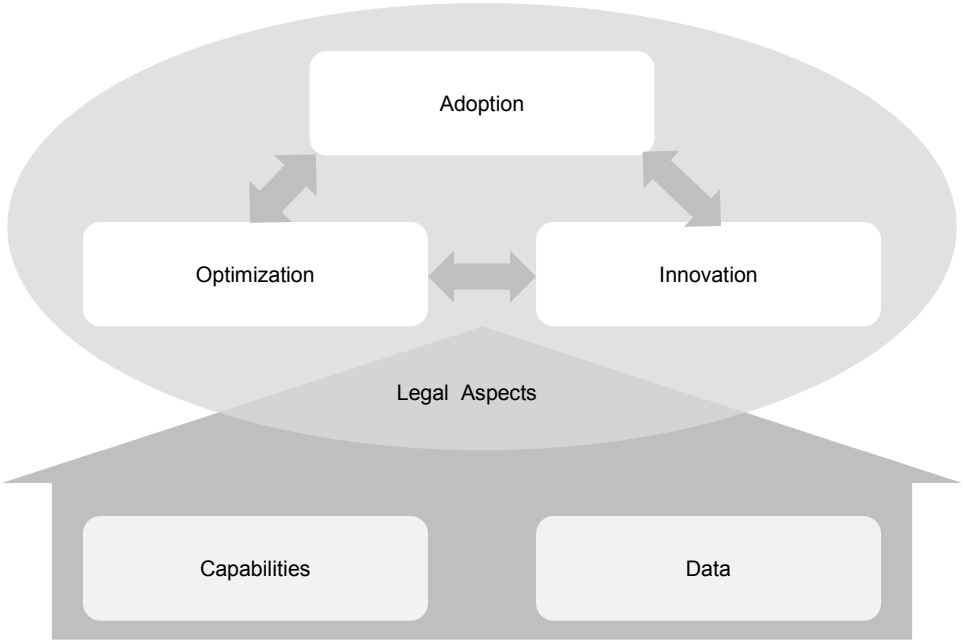
Conversely, small and medium size organizations that do not collect excessive data volumes may adopt available information technologies suiting their data volume and processing requirements. Various technologies are readily available from both commercial and free/open source vendors—making them highly cost-performance effective. Relational management framework draws from the presented relational perspective on the big data problems in organizations. This approach underscores the fact that various aspects of data affect various managerial domains. While aspects of data and its management are clearly distinguishable, they are interlinked through their influences. This enables elucidation of both individual features and their influences. The presented approach allows identification of managerial domains that play key roles in effective management of big data issues.

The pertinent managerial domains of the relational management framework arise from the interconnectedness of data aspects and relevant managerial activities. They are depicted in Figure 2. Four managerial domains are highlighted: adoption of data collection and processing methods and technologies, optimization of organizational resources with respect to big data issues, resolution of legal aspects related to acquisition and processing of sensitive data, and progressive innovation. It is important to note that the highlighted managerial domains focus on prioritization rather than completeness of the list. Different circumstances of each organization may result in a more extensive list of managerial domains.

Pertinent Managerial Domains

The pertinent managerial domains constitute the prioritized core of activities when managing big data. The presented four domains encompass the spectrum of activities ranging from the initial adoption of data acquisition technologies, throughout the processing of data and utilization of findings, to addressing the future trends and needs of organizations via innovation and reengineering. Attentiveness to the full spectrum of activities is beneficial for managers even if their organizations have already moved past the initial stages. Naturally, organizations that have deployed several technologies towards utilization of big data may be focused on later stage issues. However, several managerial issues in the earlier stages of deployments may resurface in later stages due to the connectedness of various aspects of data and its management.

Figure 2: Illustration of the Main Components of Relational Management Framework



Relational management framework builds on the novel interlinked perspective on the emerging big data challenges in organizations. The framework highlights several pertinent management domains that need to be suitably approached in order to efficiently address issues originating from data collection and processing. The pertinent management domains are adoption of data acquisition and processing technologies, optimization of available resources, innovation, and suitable management of legal issues arising from dealing with sensitive data.

Adoption

Orientation of organizations towards acquisition and utilization of extended data volumes is inevitably connected with adoption management. Big data processing and management requires proper communication infrastructure, suitable deployment of data collection technologies, and processing capabilities. These are the necessary precursors for efficient use of large data volumes. Communication infrastructures of organizations must be able to reliably sustain large volumes of data flows. Large internal data flows necessitate fast intranet connectivity, and external data flows fast internet connectivity. Internet connectivity is provided by external entities—internet service providers. External internet service providers and their services are generally independent of communication infrastructures within organizations. Hence, organizations must secure suitable services according to their external communication needs. However, intranet connectivity is under control of organizations. Legacy communication infrastructures are unsuitable for handling large data flows. They may require significant reengineering and upgrades. Proper management of infrastructure reengineering is a crucial task, since communication infrastructure is a backbone for data transmissions. Data collection technologies and processing capabilities are additional key factors in big data utilization. Benefits of big data adoption rely on quality of data and its processing. Deployed data collection technologies must provide data of desirable quality. Otherwise, no processing technologies and algorithms can provide beneficial outcomes. Analogously, having quality data without capabilities to process it is equally futile. Hence, it is necessary to maintain suitable balance between the collected data volumes, quality and processing capabilities.

Optimization; Beneficial deployment and utilization of big data technologies require adequate resources. Big data technologies are resource intensive—leading to various challenges in suitable resource management. Challenges arising from managing big data necessitate proper optimization of resources. Adoption of big data technologies affects human, financial and physical resources. Novel technologies

facilitating beneficial use of big data require personnel changes and retraining. Due to the relative novelty of big data technologies, the demand for qualified and experienced professionals significantly exceeds supply. Operation and utilization of data processing and analytic systems require well-trained professionals—ideally, with advanced degrees in data science or analytics. Unfortunately, data science programs have only recently been emerging at universities. It will take several years to produce sufficient number of qualified professionals. Presently, this gap is being filled with professionals trained in information and computer sciences, engineering, mathematics and physics. Another option for organizations is to train their own professionals. However, this takes time and investments. Physical resources such as storage, computing and communication equipment also require significant investments. Their deployment also takes time and is associated with high initial costs and adoption issues. Organizations may balance requirements for new resources with the utilization of the existing ones. Cloud computing technologies allow such balancing (Géczy et al., 2012). Existing organizational resources need to be well optimized in order to manage big data utilization at desirable pace and affordable costs.

Innovation: Maintaining competitive and strategic advantages for organizations requires continuous innovation. Utilization of big data incorporates deployment of technologies with varying lifespans. The longest lifespan is considered for communication infrastructures. Medium lifespan is assigned to hardware computing resources for data processing and storage. The shortest lifespan have software technologies used in data acquisition, analytics and actionable knowledge extraction. Timely innovation should account for lifespans of various technologies. Software technologies for data acquisition, analytics and knowledge extraction should undergo the most frequent innovations. Software technologies are based on algorithms. Better and more advanced algorithms are developed and implemented relatively frequently. It is difficult to maintain a pace with the rapid development in software and implementations of new algorithms. To navigate in the maze of software products and analytic systems, it is necessary to have clearly formulated analytic targets (Bernhardt, 2004). Proper determination of analytic targets facilitates decision making for required functionalities of various data collection, processing and analytic systems.

Legal Aspects: Organizations are required to comply with legal requirements regulating data acquisition, retention and use in the legislative regions of their business. The legal requirements vary depending on the legislative regions and sensitivity of data. Data sensitivity expresses the level and amount of sensitive information contained in collected or processed data, such as personally identifiable information, confidential or classified information. Handling of sensitive data, such as personally identifiable information, is regulated in many countries. Adopted laws and regulations control various aspects of data collection, processing, retention and exposure (Joseph and Johnson, 2013). Organizations collecting, storing or processing such data must meet the legal requirements stipulated in legislative regions where they operate. They must implement proper measures and management practices that are in accordance with the effective legislations. Managing compliance with legal requirements is important and necessitates knowledge of regional legal frameworks.

CONCLUSIONS

Contemporary digital data expansion is disproportional to the progress in data processing technologies. This has resulted in a situation where data is overly big, and organizations are facing challenges with processing and managing it. These newly emerging challenges with the aspects of growing data have been referred to as big data problems. The presented approach to the issues with big data management accentuates the relationships between the aspects of data and capabilities to manage and process it. While data volume aspect is important, several other aspects play substantial roles. The aspects of data have influence on managerial issues. Hence, the emerging big data problem is expressed as a gap between required and available capabilities of organizations to adequately deal with the aspects of collected data and related management issues. This relational formulation of the big data problem distinguishes both managerial and data aspects. However, it also underscores interrelated influences between them.

The relational management framework draws from the relational perspective on big data challenges. It encompasses a spectrum of managerial domains ranging from the initial transitional issues to innovations. The presented framework highlights several core managerial domains: adoption of data acquisition and processing technologies, optimization of organizational resources, progressive innovation, and compliance with legal requirements. These domains should be given high priority in managerial considerations and decisions. However, depending on organizational circumstances, there may be additional managerial domains requiring attention. Proper prioritization of additional managerial domains is equally dependent on organizational circumstances. Managers utilizing data oriented technologies in organizations should account for both the core and auxiliary domains. Big data oriented technologies and developments are relatively new and in emerging stages. Organizations with conservative perspective on utilization of novel information technologies may delay adoption of big data technologies until they reach a reasonable level of maturity. Factors determining suitability of various big data technologies for diverse organizations require further investigation.

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