Federica De Santis

AUDITING AND MANAGEMENT CONTROL SYSTEMS IN THE AGE OF BIG DATA

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PREFACE

The explosion of the so-called enterprise data ecosystem has been intense during the last decade and it is increasing at seemingly endless pace. In the "digitization" or "datafication" era, companies worldwide must confront with the availability of unprecedent amounts of high-velocity, high-variety of complex data retrievable from both internal, and mostly external sources, combined with unimaginable opportunities to process that data with advanced analytics solutions. This trend, that has been labelled as the advent of Big Data (BD) and Data Analytics (DA) is commonly considered as the new frontier of business and social science.

Companies are thus required to face the need for a substantive innovation of the way in which business is conducted, decisions are made and controls, whether internal and external, are performed. BD and the related DA techniques, indeed, have been identified as the 21st century drivers of a sustainable long-term advantage. At the same time, organizations that decide to invest in such advanced technology, must also be aware of its distinctive challenges and risks.

The first section aims at exploring what are the main opportunities BD determines in business context with specific reference to decision-making and control processes. It has been pointed out, however, that most of the studies (both theoretical and empirical) has been developed by adopting an optimistic (perhaps too optimistic) view of the contribution of BD in conducting and controlling business. With the aim to contribute in counterbalance this optimistic perspective, an analysis will be proposed focused on the main threats that advanced technologies may pose to organizations' Information and Management Control Systems.

The second section is devoted to the analysis of the state of the art on BD and DA utilization with a focus on the Internal Audit profession in the Italian

context. On the one hand, indeed, the Internal Audit Function (IAF) benefits from a privileged access to company's processes and accounting data, that provide it with the opportunity to identify errors, inefficiencies, anomalies, frauds, and non-compliance issues. On the other, the IAF itself can benefit from the adoption of advanced technologies in order to improve the efficiency, the effectiveness, and the level of assurance the IAF provides to its main stakeholders. Basing on the latest in the series of surveys of members of the Institute of Internal Auditors (IIA), known as the Common Body of Knowledge (CBOK, 2015), the objective of this section is to give an overview of the state of play in the use of BD and DA by internal auditors in the Italian context.

The third section analyses whether and to what extent external auditors in the Italian context use BD and DA in order to perform their audit activities. In recent times academics, practitioners, and representatives of the standard setting bodies have initiated an intense debate on the potential that BD and the related DA technologies may provide to statutory audit. Based on the interviews conducted with several external auditors operating in Italy, coming from both Big Four and non-Big Four audit firm, this section aims at shedding light on the how the profession is positioned within the BD debate. Moreover, it explores what are the perceptions of the professionals about the main elements that may favour or hamper the opportunity to adopt such technologies within the audit engagements. Finally, respondents were asked on how the adoption of BD technology has impacted, or is expected to impact, on the audit firms from an organizational standpoint.

The conclusive section emphasizes that it is clear that the BD and DA phenomenon is not just a fad, but rather a reality that companies, as well as auditors, must adequately face in order to benefit from the large opportunity it gives in improving decision-making, performance measurement, as well as audit activities. Companies and auditors must also be aware of the distinctive challenges brought by BD and DA in terms of data quality, and be prepared to adequately manage such challenges, capable of eroding most of its value creation potential.

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The responsibility of the book contents is solely of the Author.

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Federica De Santis

1. MANAGEMENT CONTROL SYSTEMS IN THE AGE OF BIG DATA: OPPORTUNITIES AND CHALLENGES

1.1. Introduction

The central role information plays in conducting and controlling business has long been recognized in academic studies (Galbraith, 1968; Bertini, 1990). Information and control are bounded by a strict and circular relationship. On the one hand, information drives management's decision-making and control processes. On the other, the results of control activities represent further sources of information to be used in guiding the subsequent decision-making processes (Marchi, 2003).

The term Information and Management Control Systems (IMCS)[1] thus identifies the combination of tools, methodologies, models, resources (human as well as technical), and information set up by companies in order to understand and organize data and to transform that data into actionable information that guides decision-making processes and performance evaluation activities (Mancini, 2018).

Technology constitutes one of the most influential factors in determining changes in companies' IMCS[2]. During the last decades indeed, the fast

[1] The term IMCS was first introduced by Zappa (1927), who defines them as the complex of tools, methodologies, model, technical and human resources and information used in order to "suitably observe and organize the collected data and to transform that data into signalling values" (*our translation*). Similarly, Amaduzzi (1973, p. 4) underlined Information Systems have a twofold role. On the one hand, it provides the information needed to drive decision-making processes. On the other, it also makes available the information needed for controlling the execution of business operations and their results, so that management can verify the opportunity to adequately relate company's means to its purposes (*our translation*).

[2] It is worthy, however, to underline that technology is just one, though significant, of the factors that can stimulate changes in corporate's IMCS. Legal and governmental environment as well as the characteristics of the economic environment can exert a significant role in determining such changes. On the different levers of change in IMCS see, among others, Corsi,

development of Information and Communication Technologies (ICT)[3] has made available a set of tools and technological solutions that have enlarged companies' data collection and information management ability, also speeding up the time at which information is produced (Mancini, 2018). Technological advancements have also considerably affected the content of the extracted information, by enriching it and increasing its signalling potential, thus creating new information and control possibilities (Arnaboldi et al., 2017).

In recent years, technology have changed business rules (Visani, 2017) and new concepts have emerged in the IMCS domain, such as those of *Big Data* (BD), *Data Analytics* (DA) and *enterprise data ecosystem*. As more and more information becomes digitized, the data ecosystem continues to explode and companies worldwide can access to an exponentially increasing amount of available information (Vasarhelyi et al., 2015). In the digitization era, moreover, the boundaries between internal and external data have blurred, since it can originate from either inside the organization or from the wider ecosystem in which company is embedded (Schiuma, 2009). Businesses are thus increasingly challenged in managing that huge volume of internal and external data in order to gain a sustainable competitive advantage (Kwon et al., 2014).

BD and its related DA technologies have been labelled as "the new business and social science frontier" (Kaisler et al., 2013, p. 1003), able to influence almost every aspect of companies' decision-making, strategic analysis and forecasting (Griffin & Wright, 2015). With an increasingly growing amount of available data, coming from both inside and outside the organization, and powerful analytics tools that allow companies to analyse it in real-time, new opportunities for decision-making and control processes are emerging (Appelbaum et al., 2017).

Advancements in ICT can thus have a pervasive impact on the entire business life, affecting most of the tasks that involve the analysis and presentation of information. Modern technological tools not only increase data and information storage capacity of the organization, they also allow the development of new information and knowledge, thus unveiling new insights into firm's functioning and performance. In other words, technology can have a

K. and Mancini, D. (2010). The impact of law on accounting information system: an analysis of IAS/IFRS adoption in Italian companies. In D'Atri, A., De Marco, M., Braccini, A. M., & Cabiddu, F. (2010). *Management of the interconnected world*. Berlin Heidelberg: Springer.; Kloot, L. (1997). Organizational learning and management control systems: responding to environmental change. *Management Accounting Research*, 8(1), 47-73.

[3] Hereinafter, the terms Information and Communication Technology (ICT) will be used interchangeably with the term Information Technology (IT)

remarkable impact also on management control processes in modern organizations (Dechow & Mouritsen, 2005).

As highlighted by Dechow et al. (2006, p. 625), however, it would be misleading to merely assume that ICT and the opportunities it gives to decision-making and management control processes represent "a solution for all problems". Such advanced technological tools also poses significant challenges for companies, many of which resides in the relationship between technology and the firm's IMCS. Technology, in fact, creates connections between the company and its ecosystem, but it cannot provide the content of such connections. By using advanced technological tools within a company's IMCS, a peculiar relationship arises that gives content to the multiple connections between the entity and its wider data ecosystem.

Stemming from the above, it may be argued that ICT and IMCS relates each other in a very complex and continuously evolving way (Granlund et al. 2013). It becomes of interest, therefore, to investigate to what extent technology represents not only a resource, but also a challenge for the IMCS of the modern organizations.

1.2. Technology and Information and Management Control Systems: a multifaceted relationship

It is unanimously agreed upon by both academics and practitioners that information plays a strategic role in Management Control Systems (MCS). MCS, in fact, can be defined as a general system (or a package of systems[4]) that provides information useful for decision-making, planning and

[4] For the purpose of the present study, "a management control systems (MCS) package is a collection or set of controls and control system" (Otley & Berry, 1980). The term "package" derives from the assumption that in most contemporary organizations there are different MCSs. Such number of MCSs can form a whole system only when they are intentionally designed and coordinated to function as a single system. More often, however, different systems are introduced by different interests group in different times. When an intentional coordination between such systems is missing, then such combination of controls cannot be regarded to as a single systems, but rather one should make reference to a package of systems. On the topic of MCS as a package see, among others, Otley, D., Berry, A. (1980). Control, organization and accounting. *Accounting, Organizations and Society*, 5(2), 231-244; Flamholtz, E. G. (1983). Accounting, budgeting and control systems in their organizational context: theoretical and empirical perspectives. *Accounting, organizations and society*, 8(2-3), 153-169; Abernethy, M. A., & Chua, W. F. (1996). A field study of control system "redesign": the impact of institutional processes on strategic choice. *Contemporary Accounting Research*, 13(2), 569-606; Alvesson, M., & Kärreman, D. (2004). Interfaces of control. Technocratic and socio-ideological control in a global management consultancy firm. *Accounting, Organizations and Society*, 29(3-4), 423-444.

evaluation (Merchant & Otley, 2006). By means of the MCS, company's management can control decision throughout the organization and influence other members of the organization to implement firm's strategies (Anthony et al., 2007). A MCS is thus a combination of people, structures and processes by means of which management guides the behaviour of people within the organization towards desirable paths with the aim of facilitating the achievement of company's objectives (Kallunki et al., 2011; Merchant & Riccaboni, 2001; D'Onza, 2009). An Information System (IS) is the combination of data, technical, human and methodological resources aimed at producing information, which are communicated throughout the organization and to the external environment in order to satisfy, in an efficient and effective way, the information needs emerging from both inside and outside the organization (Marchi, 2003). It becomes apparent, therefore, that information constitutes the cornerstone of any MCS (Bertini, 1990).

In a dynamic competitive environment rationality, more than intuition, becomes the crucial driver of decision-making directed to pursue business' success (Bertini, 1990). Decisions require information (Galbraith, 1968), and information should not be conceived as an isolated phenomenon, strictly attributable to a single and specific matter of choices. Information production should rather be a systematic and ongoing process that necessarily precedes decision-making and that is organically embedded in the management system[5].

Over time, Information Systems (IS) have always evolved with the aim to reach the best alignment with the business and its MCS. On the one hand, the development of hardware and software solutions has resulted in unique architectures evolving over time. On the other, organizational structures too have developed in peculiar forms to fit their specific environmental and strategic requirements (Mukherji, p. 498). Such evolutionary dynamics can be regarded to as a broken line, characterised by the occurrence of disruptive changes, mainly attributable to three different factors (Mancini et al., 2013): technology (Bhimani, 2003), management practices and models (Granlund & Mouritsen, 2003; Sandelin, 2008; Chiucchi et al., 2012) and standards and regulation in the accounting domain (Corsi & Mancini, 2010). Nevertheless, technological advancements have often been considered as the most influential driver of change in IMCS (Dechow et al, 2007; Granlund, 2007).

[5] According to Bertini (1990) the so-called management system can be regarded to as the *subjective reality* of the firm, that is juxtaposed to its objective reality (i.e. the production system and the system of the relationships between the firm and its environment). Management, indeed, represents the intelligence of the company that dominates, supervises, controls and correct its every manifestations, thus representing the unique source of ideas, choices, and decisions that constitute the very foundation of business' life.

The role of ICT in shaping IMCS in organizations can be seen in terms of four evolutionary stages (Marchi, 2003). As will be further explained in the remainder of this section, each stage has been realized following different paths of business processes' automation and integration, which correspond to different objectives in terms of decision-making and control needs.

The first evolutionary stage started during the 1960s, when the competitive environment was characterized by a growing expansion, a relatively low cost of the production factors and a widespread available technology (Marchi, 1993). In such a scenario, the main goal of the organization was to automate time consuming manual procedures that were at the basis of firm's functioning (e.g. payrolls) (Chapman & Chua, 2003). The introduction of computer technology in business contexts, therefore, involved a large-scale routine transaction processing problems. By means of an *ex-post* approach, in fact, transaction data was automatically captured in order to issue an annual report on company's financial and economic situation (Marchi, 2003). In this first step, the IMCS strictly replicated the existing firm's procedures and technology only allowed the automation of what was previously manually handled.

The subsequent phase took place between the 1970s and the 1980s, when discussions arose concerning how technology could have been employed not just in transaction processing and data collection, but also on how that data could have been used as a source of actionable information (Chapman & Chua, 2003). In that period, companies experienced a significant growth, both with reference to their size, and in terms of managerial capabilities (Bertini, 1990). At the same time, the external environment was characterized by an increased competitive pressure that emphasized the need for having highly flexible production processes, and high-quality products in order to meet customers' needs (Marchi, 2003; D'Onza, 2009). The goal here was not just to merely automate the existing manual procedures, but rather to suitably integrate company's IS in order to support decision-making and control activities at an operational level (Anthony, 1990; Bergamin Barbato, 1991).

The increasing complexity of competitive environments in fact required companies to adequately manage production costs as well as their relationships with customers and suppliers (Marchi, 2003). In other words, the aim of this "evolved" IMCS was to manipulate transactions within a new decision support system, able to help managers in improving the efficiency and the effectiveness of business' operation (Chapman & Chua, 2003).

By the early 1990s, a new evolutionary stage has emerged. The preceding phases, in fact, resulted in a proliferation of many separate IS developed in many different languages and running on many different hardware platforms,

each of which was aimed at supporting single business processes. According to Chapman and Chua (2003), this fragmented pattern of development was largely due to the interaction between a set of different technological solutions and the perceived business problems. During this phase, environmental and technological factors played a pivotal role in radically changing the way in which companies' IMCS were conceived.

The competitive environment was characterized by a continuous need for improving business processes' efficiency in order to gain customer satisfaction. Following the ideas of Porter (1989), it seemed that the best solution was to realize flatter organizations, to reduce time-to-market and to lower transformation costs. At the same time, technological advancements significantly increased data collection and processing capabilities, making it possible to realize IS that were integrated in a single repository, accessible anywhere and anytime (Mancini et al., 2013). These integrated systems allowed information to be retrieved from many different organizational positions, and in principle they permitted any organizational object to be made visible, thus determining unprecedent levels of integration (Dechow & Mouritsen, 2005, p. 692).

The so-called Enterprise Resource Planning (ERP) systems thus emerged as a solution to the problem of fragmentation and incompatibility between the many different existing IS (Hirt & Swanson, 1999). ERP systems offered a substantive support to management control, i.e. in ensuring an efficient and effective acquisition and use of companies' resources, in steering decisions towards firm's objectives and to guide people's behaviour toward the achievement of such objectives (Anthony, 1990; Marasca, 1999; Brusa, 1994).

In an advanced level of automation, the goal is no more the mere automation of existing manual procedures, nor the creation of a specific data repository for each business problem. Rather, business problems are restated and processes are reengineered according to the opportunities and capabilities opened up by new technologies. The main aim of such evolutionary stage was thus to increase the efficiency and effectiveness of the IMCS by making it suitable in supporting modern requirements for decision-making (Liu & Vasarhelyi, 2014).

Even though ERP systems determined undeniable advantages for companies, consisting in an increased automation and integration of business processes and a significant reduction of the time taken to accomplish business tasks, the introduction of such systems have also posed some relevant challenges. The distinctive features of ERP systems, i.e. their drive towards business processes' automation, integration and standardization, caused a dramatic change in the way in which organizations could and should operate (Chapman & Chua, 2003).

Implementing an ERP system with the aim of automating and integrating business processes, in fact, implied a certain degree of standardization (Blain, 1999). Unlike people, computers need to operate within a precisely structured framework of decision rules (Giannessi, 1975)[6], and customizing an ERP system not only was very costly, but also risky in some instances. Given their inherent complexity, indeed, alterations to the standard ERP package may cause unpredictable negative implications to the proper functioning of the entire system. It may be argued, therefore, that ERP technologies have shifted "the balance of significance away from the idiosyncratic local knowledge towards the delivery of standardized outputs based on standardized input" (Chapman & Chua, 2003, p. 85).

The abovementioned features of ERP systems, however, seemed to conflict with the growing turbulence and dynamism of the competitive environment in which companies operate. Some authors have thus underlined that there emerged a misalignment between the goals of IT, which imposed standardization and integration, and companies' goals, which required high degrees of agility and flexibility to adequately face globalization issues and adapt fast to an increasingly changing environment (Mancini et al., 2013).

In relatively recent times, a fourth evolutionary stage of IMCS integration has initiated, stimulated by both contextual and technological factors. On the one hand, the hypercompetitive economic environment requires companies to further advance their MCS, by including a stronger support for strategic dynamics. On the other, the fast advancement of new technological solutions have made available new tools able to overcome some of the issues related to the standardization requirements and, to some extent, the rigidity of ERP systems (Chapman & Chua, 2003).

When the economic environment becomes highly dynamic and instable, with continuously emerging risks and opportunities, it arises the need to constantly monitor the drivers of company's competitive advantage, as well as the changes that may occur in the external environment. It becomes crucial for companies to fast adapt to the changing market conditions. In doing so,

[6] Giannessi (1975), in his reflection on whether computers may be referred to as "electronic brains", interestingly points out that it is undoubtable that computers possess unprecedent processing speed, far greater than that of people. However, such a great operational speed can manifest itself only with reference of tasks that are programmed (i.e. set up) by people. Without a specific program to which refer, computers, despite their great speed, are useless. In other words, computers enable high degrees of automation and velocity, but they repeat "stupidly" what a programmed framework of rules imposes them to do. When computers operate according to a well designed framework of rules, than they assure also great levels of accuracy of the processed data. Otherwise, they will indefinitely repeat a wrong data processing rule. Giannessi, E. (1975), *Cervelli umani ed elettronici nella vita aziendale*, Pisa, Cursi.

companies need to implement new mechanisms of control, able to monitor and evaluate the results of the deliberated strategy before its enactment and during its execution (Paolini, 1993).

Stemming from the above, one should not erroneously conclude that traditional (i.e. operational and managerial) control mechanisms are no more required. The need for ensuring the efficiency and effectiveness of business processes does never fail. However, such mechanisms should coexist and be integrated with more strategic-oriented controls (D'Onza, 2009).

IT can, again, represent a strategic driver in enabling more complex and sophisticated MCS (Clark et al., 2007, p. 588; Davenport & Harris, 2007, p. 98). Specifically, advanced technological solutions such as the so-called Business Intelligence (BI) tools provide organizations with the ability to collect and analyse increasingly vast amounts of data, both internal and external, in order to support strategic decision-making and control processes (Marchi, 2003). The term BI can be regarded to as an *umbrella concept* that was initially introduced by Howard Dresner from Gartner Group in 1989[7]. This expression, indeed, encompasses those tools, techniques and solutions that gather company data as well as market data transforming it into information or knowledge about the objectives, opportunities, and position of an organization (Foley & Guillemette, 2010).

Global and turbulent competitive environments challenge companies to elaborate meaningful indicators of its performance. Moreover, it emerges the need for being able to timely catch feeble signals coming from the external environment about the risks and opportunities that may hinder or facilitate the achievement of company's strategic plans, in order to promptly react to the changing conditions. Operating in hypercompetitive environments also aggravates company's challenges to effectively manage the more and more interconnected business processes. Data analysis has thus become an even more strategic task for business success (Rikhardsson & Yigitbasioglu, 2018), and BI solutions has been developed in order to enrich the existing IMCS infrastructure by enabling companies to realize continuous monitoring of business processes, in-depth data analyses, and efficient management communications (Eckerson, 2011).

The advent of so-called BD and the related DA technologies may be considered as a further development of this fourth stage of IMCS evolution. BD

[7] For a more comprehensive understanding of Business Intelligence tools see, among others, Wieder, B., & Ossimitz, M. L. (2015). The impact of Business Intelligence on the quality of decision making–a mediation model. *Procedia Computer Science*, 64, 1163-1171. Michalewicz, Z., Schmidt, M., Michalewicz, M., & Chiriac, C. (2006). *Adaptive business intelligence* (pp. 37-46). Springer Berlin Heidelberg.

indeed may be considered as one of the most representative paradigms of the complexity and turbulence of today's knowledge economy (Secundo et al., 2017) as it reflects the exponential growth of the amount of information made available by the fast developments in computing and ICT that occurred in recent times (Vasarhelyi et al., 2015). During the last decade, indeed, we have witnessed a "datafication" of the world (Mayer-Schönberger and Cukier, 2013), that is to say that "almost anything can be recorded, measured, and captured digitally, and thereby turned into data" (Cao et al., 2015, p. 423).

The enterprise data ecosystem is thus expanding at a continuous and seemingly accelerating pace. Companies are now submerged by data that is being created and collected in a near-continuous flow, coming from both internal and external sources, in structured, semi-structured and unstructured form. Organizations are thus challenged to find the best way to exploit that data in order to improve their efficiency, effectiveness, and competitiveness. According to Kiron et al. (2013, p. 2) "we are on the cusp of an analytics revolution that may well transform how organizations are managed".

From the analysis of such evolutionary dynamics, it emerges that the shift from the third to the fourth stage constitutes the most significant change in the IMCS domain. First, there has been a change in the sources of information. While during the third stage companies fundamentally relied on internal data stored in the ERP systems for analysis, now most of the available data comes from external sources and, even more importantly, it consists of unstructured data (e.g. data from social media, Internet websites and sensors). Second, both data processing and information delivery processes has changed significantly. In the age of ERP, integrated information systems' goal consisted in facilitating the diffusion of knowledge throughout the organization and supporting control activities aimed at guiding people's behaviour towards the accomplishment of firm's objectives. In this fourth evolutionary stage, instead, the goal pursued by integrated information systems relates to the earlier processes of knowledge generation and objectives setting. Finally, ICT does no more only represent a supportive tool for decision-making and control processes. It becomes, instead, a strategic competitive driver (Davenport & Harris, 2007), able to increase the efficiency and effectiveness of internal processes, strengthen firms' external relationships and to support the creation and maintenance of a sustainable competitive advantage (Marchi, 2003).

To sum up, the analysis of the evolutionary dynamics of the IMCS has shown that technology, control and environmental factors are strongly intertwined and contribute together to the objectives and features of IMCS. Specifically, technology plays a central role in establishing the management control agenda by means of integration. It is worthy, however, to underline that the

impact of technology is always mediated by the context in which it is introduced (Dechow & Mouritsen, 2005). In other words, when new technological solutions are introduced in an organization, such solutions not only act on the architecture of the existing IMCS, but it is also acted upon by people within organization. The relationship between technology and IMCS should thus not be assumed as a unidirectional one, but as a multidirectional relationship that assumes unique architectures evolving over time (Mukherji, 2002).

Moreover, the study conducted by Dechow and Mouritsen (2002) has highlighted that integration through technology should not be considered as a solution *per se*. Rather, it represents a means for problematizing business processes and through which people in the organization look for ways of spreading knowledge across localities in order to meet the needs and requirements of many different parties in different places. That is to say that integration "is less a goal than a problematizing activity" that can never be fully realized. In fact, integrating the IMCS of a firm by means of technology implies imposing a so-called techno-logic that defines how controls can be performed. The relationship between technology and its use is context-specific, thus it represents both an opportunity and a challenge for firms that decide to invest in it (Dechow et al., 2007).

We discussed in this section how at the second stage of integration, the IMCS of the company becomes able to support operational control, but fails in supporting managerial controls due to the proliferation of different IS that are scarcely integrated one another. When ERP systems are introduced, companies can overcome the problem of fragmentation and incompatibility between the many different existing IS. However, because they need a certain degree of standardization to effectively function as knowledge-spreading and control-supporting tools, ERP systems fail in providing companies with the required agility and flexibility to adapt to a highly dynamic and turbulent competitive environment. Technology therefore, has evolved in order to provide organizations' IMCS with more advanced tools, able to support business in their new requirements. As underlined by Dechow and Mouritsen (2005, p. 731) "*management control and technology perform as a continua of the same business-oriented discourse: what are we doing and where are we going?*".

1.3. The Big Data environment

As mentioned earlier, the concept of BD has emerged in relatively recent times with the increasing "datafication" of the world, in which everything in

the business as well as in the physical world can become a source of data (Bhimani & Willcocks, 2014). However, BD as a research field finds its roots in practice rather than in academia, so that only recently scholars have shown an interest on the topic and have not reached yet a clear and unanimous definition of this concept.

Over time therefore practitioners have proposed different interpretive frameworks aiming at identifying in a clear and intuitive manner this multifaceted and ambiguous concept. The most widespread definition of BD, the so-called 3Vs framework, stems from a preliminary set of its distinctive characteristics, i.e. volume, velocity and variety (Laney, 2001). Starting from the 3Vs model, researchers and practitioners have described other key features of BD, so that the original interpretive framework has evolved including also data value, data veracity and data variability (Gandomi & Haider, 2015).

As defined by Gartner, Inc. "*Big Data is high-volume, high-velocity and high-variety information assets that demand cost-effective, innovative forms of information processing for enhanced insights and decision-making*" (Gartner IT Glossary).

Volume refers to the amount of available data, that either consume huge storage capability or consists of a large number of records. Data indeed is considered "Big" only if it pushes the usual limits of an IS, thus requiring not only advanced capturing and storage tools (Chen et al., 2014) but also, and far more importantly, in terms of data processing capabilities (Vasarhelyi et al., 2015).

Velocity may be defined as the time taken to generate and deliver data and represents one of the most challenging attributes, as it implies that not only BD consists is huge amounts of data, but also that this data is complex, continuously flowing and fast-generated. Velocity requires data to be analysed and acted upon in real-time in order to create value and gain competitive advantage. Strictly related to the velocity attribute is data variability, that refers to the fluctuations of the data flow rate, which is subject to periodic peaks and troughs (Gandomi & Haider, 2015).

Variety is related to the structural heterogeneity within a data set, that is to say that data is generated from a great variety of sources and formats and that they contain multidimensional data fields (Russom, 2011). Variety, therefore, consists in a qualitative attribute referred to the richness of data representation, that allows to distinguish between structured, semi-structured and unstructured data (Kaisler et al., 2013). The challenging aspect of such attribute relates to the conceptual difference between data and information. As underlined earlier, within a company's IS, data constitutes the raw material of the process of information production. Through this process, in fact,