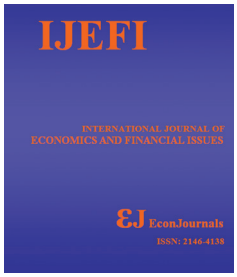

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Risk Management 4.0: The Role of Big Data Analytics in the Bank Sector

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ABSTRACT

The need to query large volumes of heterogeneous data in differing formats from multiple sources, both internal and external and its centrality to the process of value creation is revolutionising traditional approaches to business models. Through the adoption of more sophisticated algorithms, it is possible to intercept and interpret any digital flow, particularly those coming from the Internet of Things or from the web. The vast amount of information, its governance and its global integration are used in all decision-making processes and they are, therefore, an element of strategic importance in the development process and in the survival of every company, thanks to the potential for transforming all information sources into knowledge and quantifying reality in all its elements (objects, places, phenomena, people and human behaviour). Having a large volume and a wide variety of information (i.e., Big Data) shared within an organisation is crucial for the interactive and multidirectional process of risk assessment and management. This process, on the one hand, contributes to safeguarding the integrity of corporate assets through increased efficiency and the effectiveness of the services provided and, on the other, reduces unexpected events and related losses while ensuring greater efficiency in the decision-making process. This is relevant especially in financial institutions in which risk management is pivotal to their survival and their success, assuming a strategic role. Through an analysis of the literature and a case study methodology, this paper investigates how small banks are facing technological challenges, showing the state of art about the actual use of the techniques of data collection and management (e.g., Big Data analytics [BDA]) in supporting the risk management process. Furthermore, the work tries to identify the skills required of the risk manager in the digital age. The paper contributes to the ongoing debate on the usefulness and use of digital innovations in the banking sector, discussing the future perspectives of risk management 4.0 and the role of BDA in risk management.

Keywords: Big Data Analytics, Business Intelligence, Risk Management, Decision Making, Case study, Banks
JEL Classifications: O3, G2, M1

1. INTRODUCTION

Since the 1990s, the increase in competition worldwide and the availability of structured and unstructured information have deeply changed companies' production and organisational processes, making it necessary to improve upon traditional management and data analysis systems (Vasarhelyi et al., 2015). To extract value from information, it is necessary to consider the systematisation of knowledge through the creation of archives and the management and analysis of data produced in large quantities (volume), with rapidity (speed) and in different formats (variability). This was the starting point for the evolution of business intelligence through the

implementation of software dedicated to information processing, services to integrate new technologies with existing systems, and infrastructural resources with an increase in computing and storage capacities for data from which to derive new levels of knowledge (Big Data analytics [BDA]).

This new paradigm in the digital era requires the support of multiple skills and the knowledge of programming techniques and allows a better interpretation, inspection, cleaning and modelling of large amounts of data extracted from various sources (including the web) that are useful in the decision-making process (Warren et al., 2015). The data coming from the web plays a crucial role in the context of Big Data, considering its high information potential, especially in forecast analysis. Operational data sources include accounting applications and personnel and customer management, which are appropriately integrated with other segments, such as production management; purchasing and delivery applications for companies; industrial and branch management; financial instruments; and risk assessment for banks.

In recent years, the process of sharing information both internal and external, and particularly concerning risk, governance and performance, is increasingly supported by the evolutionary paths of new technologies, creating the premise for a gradual revolution of business and organisational processes and placing itself as the foundation of the 'fourth industrial revolution' (Manyika et al., 2011). The collection of large amounts of data in a heterogeneous, redundant and unstructured form (Big Data) and its interpretation, analysis and evaluation mainly follow risk-based logics that are primarily focused on credit, operational and compliance risks (e.g., the GDPR directive and anti-money-laundering legislation). The importance of Big Data emerges most notably in the financial, banking and insurance sectors due to their supervision authorities (e.g., European Central Bank, European Security and Markets Authority), which impose stringent capital regulations.

The amount of data acquired through digital technologies and multi-channelling with the adoption of BDA could support the maximisation of global business value thanks to the alignment of strategic priorities for risk management activities, the timely reporting of sources of uncertainty on which to focus attention, and the implementation of specific actions to improve performance. The knowledge and measurement of risk and the subsequent identification of anticipatory and proactive actions constitute priority activities that affect the achievement of strategic objectives through the assignment of specific responsibilities to all company levels and the creation of an efficient reporting and communication system. In this sense, the support of communication (top-down and bottom-up) within an organisation is fundamental, as is the proliferation of relevant information for the census and filing of all external risks to business processes and information for decision-making.

Greater uncertainties, linked to political, regulatory, macroeconomic and technological factors, have ensured that risk management activities have taken on both increasingly broader connotations and a continuous and integrated approach aimed at mitigating risky events with widespread responsibility inside a company's organisation. The implementation of adequate risk management policies and programmes requires the involvement of the highest levels of the corporate hierarchy to define the essential principles for protecting internal and external subjects (social responsibility) and safeguarding business continuity and generating value over time (behavioural ethics). The rethinking of organisational models to focus them to a greater extent on a systemic view of corporate risk was inevitable (Floricel and Miller, 2001; Rasmussen, 1997). An important contribution to the formalisation of the new risk management approach has been provided by several standards, of which the most complete are the International Organization for Standardization (ISO)/IEC 31000 Risk Management principles and guidelines and the Committee of Sponsoring Organizations (CoSO of the Treadway Commission) Enterprise Risk Management integrated framework, which include principles and guidelines for the integration of the risk management process into the overall governance of an organisation, from the strategic planning process to the reporting policies.

The present work investigates the level of implementation of advanced technological infrastructures adopted by small banking institutions and their ability to identify and create an effective risk management process in light of the limits established by internal regulations (risk appetite) and supervision. This is a phenomenon still little investigated in the literature, despite risk management representing an area of great importance, given the central role that banking intermediaries have in the economic fabric and the consequences of their bankruptcy.

The work is structured in five sections. Section 2 presents the review of the literature on Big Data and risk management, with a particular focus on the banking sector; Section 3 is dedicated to the description of the methodology; and Section 4 discusses the results, focusing particularly on the importance of using advanced technological infrastructures in identifying, assessing and mitigating risks. Finally, Section 5 presents the conclusions.

2. LITERATURE REVIEW

2.1. The Role of Big Data in the Digital Economy

Big Data already existed at the end of the 1990s and has spread enormously in the 21st century, becoming, in the current context, a key element for modern business. Companies all over the world are exploring these large volumes of highly detailed data to discover previously unknown information that is useful in improving the decision-making process (Hasnat, 2018).

Big Data refers to sets of data so large that they cannot be used with traditional database management systems because their dimensions overwhelm the capability of the software tools and storage systems commonly used to acquire, store, manage and process data within a tolerable time frame (Hasnat, 2018). Generally, Big Data refers to enormous series of data, both structured and unstructured, with wide, varied and complex structures, which is generated, captured and stored at incredible speed (Sagiroglu and Sinanc, 2013; Srivastava and Gopalkrishnan, 2015). Some authors define Big Data resources as high volume, high speed

and high variety, requiring innovative and economical forms of information processing—so-called huge information—for better understanding and decision-making capability. Differently, for other researchers, Big Data indicates not only the set of data, but also the set of technologies that carry out all the functions mentioned and that exploit the value of the data and make its use economical and effective (Lackovic et al., 2016).

The literature identifies three main features that characterise Big Data, also known as the 3Vs: (i) Volume, (ii) velocity and (iii) variety (Ozkose et al., 2015; Sagiroglu and Sinanc, 2013). Volume refers to the quantity of data and, therefore, to the dimensions of the dataset. Regardless of whether it is important, the data is very large. Velocity refers to the speed of the data flow, that is, the rate at which the information is generated and spread and therefore the rate at which it is processed and analysed (velocity of data and processes). Variety is the characteristic that makes the data 'big' and is related to the typology of the information sources and the generated data, which can be structured, unstructured or semi-structured and can derive from different sources, both internal and external. Some researchers attribute to Big Data two more characteristics: Variability and veracity. Variability concerns the periodicity—or irregularity—and, sometimes, the incoherence of the data (Elgendy and Elragal, 2014). Veracity concerns the accuracy of the data, which can be good, not good or undefined, with the data potentially being incoherent, incomplete or ambiguous (Gandomi and Haider, 2015; IBM, 2014). Some authors identify a further characteristic, value, referring to the potential value of the data (Choi et al., 2017; Ozkose et al., 2015).

In 2015, the United Nations Department of Economic and Social Affairs classified Big Data into three categories according to the different sources from which it derives: Data from social networks, including information from social media, messages and research conducted on the internet; data from traditional systems of business, such as that generated by commercial trade transactions, e-commerce, credit cards and medical records; and data from the so-called Internet of Things (IoT), referring to machine-generated data, such as that concerning weather and pollution, data from GPS satellites and data from computer-based registers (Hasnat, 2018).

The process of extrapolation of information is articulated in two phases: The first, known as data management, consists of the acquisition, storage, selection and representation of data; the second, called analytics, is composed of all the activities focused on the analysis and interpretation of data (Gandomi and Haider, 2015; Krishna, 2016). Data is first extracted through information system tools from external sources, then transformed and loaded into advanced databases or data warehouses. The data can then be cleaned and classified before making it available for data mining and other forms of analysis. Finally, it is processed and submitted to the BDA tools necessary to make the Big Data useful in the decision-making process (Munesh and Mittal, 2014).

In the literature, BDA is defined as the processes that, using algorithms, analyse data sets to extract diagrams, reports and useful and unknown information. It is used to extract models and information that is valid, useful and previously unknown or hidden in large data sets, as well as to identify important relationships between variables, thus ensuring a competitive advantage (Elgendy and Elragal, 2014). Other authors consider BDA to be the tools that can generate intuitions useful in the decision-making process, assess company business performance, establish competitive advantages and, therefore, increase enterprise value (Saggi and Jain, 2018).

Such a large and varied data set requires a capacity for storage, management and analysis that common software does not have. Indeed, traditional databases or data warehouses are insufficient and are unable to address the problems of selection, adaptability and usability of data—essential characteristics for the use of Big Data to achieve its expected benefits for improvement of the decision-making process and, consequently, an increase of business value. The rapid evolution of technology and the exponential increase in the data flow available has made necessary the development of more rapid and efficient tools for both the conservation and analysis of this data (Elgendy and Elragal, 2014). This has led to the development of advanced BDA based on tools such as NoSQL, BigQuery, Map Reduce, Hadoop, Flume, Mahout, Spark, WibiData and Skytree (Saggi and Jain, 2018), which can collect and analyse large and varied data very quickly to detect hidden models, unknown correlations, market trends, customer preferences and any other information considered useful.

Many businesses are making huge investments in BDA tools, to the point of making the analytics market one of the fastest growing in IT. However, the first empirical evidence of a positive impact on the performance of companies that have adopted these kinds of tools has appeared only recently (Muller et al., 2018). Research conducted by TDWI, a leading company in the sector of business intelligence, notes that the use of BDA tools has brought benefits in terms of better intuition and comprehension of business changes, better recognition of market opportunities, more focused marketing, automation of decision-making processes, more accurate quantification of risks and better planning and prevision. The same study, based on surveys administered to BDA users, observes that the major obstacles found in the use of this type of tool are connected to the inadequacy of the existing infrastructure, the high costs of implementation or adjustment and the lack of skills and specific knowledge (Sagiroglu and Sinanc, 2013).

A study conducted by Manyika et al. in 2011 underlines the major advantages of the use of BDA tools, which are in the areas of customer in-depth knowledge (customer intelligence), supply chain knowledge (supply chain intelligence), performance analysis, quality management, risk management and fraud detection (Ravisankar et al., 2011). Other researchers observe that the sectors that could benefit most from the use of Big Data are manufacturing, retail, central administration, healthcare, telecommunications and banking.

In the literature, there are still few studies concerning the use of Big Data in the banking sector, but, in the last decade, growing interest from researchers and sector experts has been observed. Numerous studies highlight the positive relationship between the use of technological innovations in the banking sector, including

technologies based on Big Data, and business productivity. Specifically, banks that use BDA have an advantage of 4% in market share over banks that do not (Hossein et al., 2018).

Many researchers note that technologies relating to Big Data are applicable in many areas of the banking sector, including retail (bank collections, credit cards, private banking), commercial (credit risk analysis, customer and sales management, middle market loans), capital markets (negotiation and sales, structured finance) and asset management (wealth management, management of capital investments, global asset reporting, analysis of investment deposits) (Lackovic et al., 2016; Mohamad et al., 2015).

However, most studies show that the areas of greatest use of Big Data in the banking sector can be grouped into customer relationship management (CRM), fraud detection and prevention, and risk management and investment banking (Hossein et al., 2018; Kathuria, 2016; Radmehr and Bazmara, 2017; Srivastava and Gopalkrishnan, 2015). In the following section, after illustrating integrated risk management, we will focus on the employment of BDA in risk management to appreciate the usefulness of these tools of storage, interpretation and management of data.

2.2. Risk Management in the Big Data Era

The correct functioning of a business activity and the contextual creation of an enterprise's economic value cannot neglect monitoring of the main risk factors, as represented by financial and managerial indicators whose economic effect can compromise performance. The clear and evident interconnections and interdependences between business risks have led to an increasingly global management of enterprise risks following a systemic approach that is coherent with the growth path of a company and a contextual transversal analysis of heterogeneous processes, functions and activities (Bhimani, 2009; Liebenberg and Hoyt, 2011; Ellul and Yerramilli, 2013). It follows that, in the last few years, overhauling of the traditional approach characterised by a mainly sectorial and fragmented view of risks ("silo" management) has resulted in the spread of a new philosophy in the management of business risk that involves the whole organisational structure and affects strategic and operational processes. This approach is known as enterprise risk management (ERM) and provides for integrated risk management through an analysis of business contingencies and an evaluation of uncertainty, with organisational solutions recognised and shared by the whole company, with the aim of business continuity (Beasley et al., 2008; De Loach, 2000; Idris and Norlida, 2016; Liebenberg and Hoyt, 2003, 2011; Navak and Akkiraju, 2012).

At the operational level, important international contributions have come from ISO and CoSO, which have outlined a series of principles and operational techniques for a more systematic and disciplined approach to risk management through the interaction of adequate control systems with performance and business strategies. These strategies, even if they are in a state of uncertainty, can lead to the creation, maintenance and realisation of value and, hence, to the satisfaction of the stakeholders' expectations for long-term sustainability. In recent years, the integrated risk management approach has been implemented by a growing number of companies in light of its competitive advantages, its increase in the economic value of business capital (Arena et al., 2010; Beasley et al., 2008; Boscal et al., 2010; Liebenberg and Hoyt, 2011; Nocco and Stulz, 2006; Woods, 2007), the improvement of operational performance and the reduction of the risk of failure (Florio and Leoni, 2017; Gordon et al., 2009; Grace et al., 2015) and in the awareness that 'in order to create and protect the value of an organisation it is essential to manage the risks in a structured way and based on well-defined principles' (ISO 31000:2018).

The recent financial crisis and the continual modifications made to the regulatory framework have led to the diffusion of new models of risk management in the banking sector, especially in light of the move from strategies based on the observation only of losses that have already occurred (incurred loss) to those characterised by the preventive evaluation of risks with a forward looking approach based on expected losses (IFRS 9 – Financial Instruments). For this, banking institutions pay particular attention to financial transactions, stress tests, scenario analyses and risk reporting in order to understand the different typologies of the sources of uncertainty to which the bank is exposed (Hossein et al., 2018). There is therefore a greater awareness of risk-taking and greater selectivity of the purposes thereof, thanks also to proactive involvement and communication of top management with supervisors.

It is obvious that banks increasingly need to use all available data to predict risks, manage them and report them. The quantity and quality of data are essential elements for the formulation and implementation of strategies compatible with risk appetite and suitable for structuring effective and reliable processes and procedures for safeguarding the integrity of bank assets. This has not only required a revision and adaptation of organisational models, but also emphasised the importance of technology in both the automation and integration of the various processes (stress testing, modelling, monitoring, reporting, capital planning, etc.) and in the management of big volumes of irregular data from which, by means of advanced analytics systems, it is possible to draw information useful to the management of organisations and processes (Hu et al., 2012). According to research conducted by Deutsche Bank (2015) and McKinsey and Company (2015), the increase in banking tools and transactions, the subsequent explosive growth of data, the increasingly innovative use of statistics and mathematical sciences of risk management, the development of new typologies of risks and, above all, the increasingly stringent regulation and attention have had an immense impact on the data underlying the information and technological infrastructure (Lackovic et al., 2016) that play an increasingly central role in the value creation process. The intent is to ensure that banks can integrate traditional data coming from various channels—traditional counters, internet and mobile banking, ATMs, ASDs/ASSDs (assisted self-service devices), credit circuits and e-commerce platforms—with unstructured data, especially from social networks and the web, through the creation of a data lake. This is a platform that allows storage, organisation, management and operational exploitation of large volumes of data to return helpful information and knowledge of the consumption habits and risk profiles of customers for fraud

detection (Banarescu, 2015; Chen et al., 2015) and the streamlining of processes and products, such as contract management, compliance analysis, complaint management and the optimisation of decision-making for credit risks.

Many authors support the idea that rapid identification and quantification of new risks and a transparency in reporting activities are essential in risk management (Elgendy and Elragal, 2014; Lackovic et al., 2016) to integrate traditional information sources with unstructured data acquired from various internal and external sources (Word, Excel, PowerPoint, images, e-mails and information from the internet) using advanced technological tools and new data-intensive techniques for the construction of a shared platform—the so-called BDA (Elgendy and Elragal, 2014; Lackovic et al., 2016). These advanced tools include data sourcing tools that find data in a timely, accurate and complete way; data processing and retention tools that process and store data in an efficient way and support historical analysis; data analytics and data reporting tools that conduct advanced analyses and detailed reporting; data management tools that manage access, storage, distribution and quality of data; and data governance and control tools that govern and control data with reference to property, responsibility and organisational standards concerning usability, accessibility, accuracy and consistency of data (Krishna, 2016).

Lackovic et al. (2016) develop a framework in which they suggest the use of Big Data in each of the four key risk management activities (identification, assessment, management and control, and reporting). The framework can be articulated as follows:

1. Risk identification: Identification of new sources for the early identification of risks and in-depth knowledge of customers;
2. Risk assessment: Analysis of underlying information through the calculation of various risk indicators, real-time simulation of risk indicators and predictive analysis for all typologies of risk;
3. Risk management and control: Reputational risk management, operational loss forecasting, compliance management and real-time control of financial risk; and
4. Reporting: Real-time creation of reports, calculation of risk exposure on request, increased transparency and real-time stress tests.

Business intelligence and Big Data tools, in the current competitive context, are key tools for increasingly effective strategic management thanks to the development of programming languages and statistical techniques that both allow exploitation of the predictive capacity of data analysis and make the knowledge patrimony clear, comprehensible and usable in a strategic way at all levels of an organisation. For such innovation, it is not enough to create advanced digital platforms that can direct, process and understand information flows; it also inevitably requires a cultural change, with the inclusion in the organisation of new resources with suitable knowledge of mathematics, statistics and the technological innovation necessary to process large volumes of data quickly and return knowledge (Edwards and Taborda, 2016).

The literature shows how Big Data can be a crucial element in risk management systems, especially in predictive analysis of credit institutions. Large banking groups have an organisational structure that can support innovations in the IT field, but the collection and management of data by smaller banks remains an open question.

Starting from this premise, the present work intends to answer the following research questions:

1. What are the techniques of collection and processing of data currently employed by small banks in the area of risk management?
2. How can data management technologies affect the risk management process?
3. How will the use of Big Data affect the risk manager's skills?

3. METHODOLOGY

To answer the research questions, a case study methodology was used (Yin, 2014), as it was considered particularly suitable for observing a complex phenomenon (Eisenhardt, 1989), such as the one in question. The survey was conducted using a single case study—a credit institution presenting the typical characteristics, in terms of organisational structure, of a small bank. Based on the objectives of the research and the current phase of the development of Big Data in risk management, the analysis of the case study was of an exploratory nature, to provide preliminary explanations for the research questions, which will need to be expanded through subsequent empirical investigations.

A semi-structured interview with open answers was conducted with the credit institution's head of risk management, to understand the effective use of Big Data in the risk management function. The interview, lasting about 60 min, was conducted at the bank's headquarters, which allowed observation of the organisational structure in terms of both human and technological resources.

The interview was structured based on three survey profiles:

a. Risk management and information technology actually used in risk management;
b. Future perspectives about the use of Big Data; and
c. New risk manager skills.

4. RESULTS AND DISCUSSION

4.1. Context Analysis

The bank selected for the analysis in the present study is located in Italy and was founded in the 1960s. The bank operates more than three hundred branches, with about 3000 employees. As of 31 December 2018, operating income was >€343 million. The business segmentation of customers ensures the achievement of business objectives, such as improved customer relationships, greater satisfaction of the requirements of customers with suitable products, improved efficiency of the analysis and monitoring process. Within the credit institution, there is a risk management office and an IT development office.

4.2. Current Model of Risk Management

The bank, although it has not yet fully adopted BDA tools, has created a sophisticated data architecture to gather and analyse a

large volume of data that must be translated for it to be helpful to the decision-making processes. The first implementation was conducted in the risk management area and later extended to other business areas.

The data derives from internal and external sources and is collected in a large data warehouse—an information system that integrates and organises information that is generated frequently in the different business areas. The analysis of this large amount of data is carried out with tools and models that have been developed and are very similar to those used for Big Data.

The risk management function developed, on the basis of the available information, innovative internal predictive models (predictive analytics) of the evolution of the economy, financial stability and the measures that are characteristic of banking activity, such as default and credit. Such estimations are reported in official documents provided to the supervisory authorities with a detailed indication of the calculation methods. The data analysis tools available to the bank support the decision-making process as they can propose operational and strategic solutions (prescriptive analytics). This data management is more developed than was originally intended and it has a very wide range of uses and is the basis of all the typical quantitative analyses: Risk assessment, forecasting analysis, stress tests and testing and development of models of whatever nature and form. The greatest benefits of such sophisticated data architecture are mainly found in credit, operational and financial risk management and in the controls in the Markets in Financial Instruments Directive (MiFID).

4.3. Future Perspectives on the Use of Big Data

From the interview, it emerged that the attention and interest of risk management in large amounts of data and the resulting information have led the bank to make numerous investments in advanced IT technologies. Many investments of this type have already been realised, while others are in progress and yet others are likely to be realised in the future, "to make a qualitative leap and move towards more Big Data management," as declared by the interviewer.

The current data structure has required important organisational changes and very expensive investments. Advanced software has recently been acquired for data management, and ad hoc servers have been purchased for storage, as well as very expensive licences for their use. The bank is also evaluating the use of advanced vision analytics tools for more immediate and accurate readings of the amounts of data and for more precise and detailed analyses. The advantages of the implementation of these new architectures will be observed in the long term, and improvements in business management and value creation for the company are expected.

Risk management—especially credit and reputational risk management—through BDA technologies would allow the bank to use its huge amounts of data more effectively and to extract more precise, detailed and accurate information. Real-time implementation could help the risk manager to be more timely and precise in risk identification, assessment and mitigation and to extract hidden value from the data using new data quality monitoring metrics that are useful for non-quantifiable typologies of risk. The dimensions and complexity of the data generated in the bank by the numerous daily transactions in its operational systems ensure that future investments will be increasingly directed towards technologies based on artificial intelligence that can process huge amounts of data quickly and extract value from Big Data, returning helpful information that is usable in real time.

However, from the interview emerges that small banks have not yet implemented an effective IT system based on Big Data. This is because there are necessary huge investments, the well-structure organisation and a cultural change of management.

4.4. New Risk Manager Skills

The adoption of Big Data in risk management can create an important competitive advantage. However, the management of a highly variable amount of data in real time requires not only new tools and methods, but also the broadening of IT, statistical and mathematical knowledge, mainly oriented to quantitative analysis of data to interpret and transform it into high added-value information. Recent investments in technological infrastructure have modified the activities of the risk managers and the IT staff who deal with the new software and computer systems. This has required the development of new knowledge and skills essential to the conversion of data into a strategic resource.

It emerged from the interview that strengthening of the technological infrastructure, promoted by risk management to support risk management activities, is taking place. There have been important investments in more sophisticated software for the retrieval, management and analysis of data, and further progress will be made towards management of information based on the use of Big Data technologies, with benefits from the main information produced and its promptness. Indeed, sophisticated information technology architecture has resulted in the identification of new potential risks and in more precise and accurate risk calculation models, thanks to the newly available data and the new indicators and quantitative analyses derived from therefrom. All this entails a change in the skills required of a risk manager, who must have more quantitative skills in the management and analysis of data.

5. CONCLUSIONS

The continuous evolution of the banking system, together with regulatory, cultural, scientific and technological changes, has required the development of new approaches to be integrated with the traditional sectorial tools that are inadequate for managing complex, unstructured and disorganised data. Regarding organisational changes, the adoption of BDA is still at an embryonic stage, even though data management systems with better analytical capabilities—especially predictive and textual analysis—have been introduced. It emerged from the interview that the optimisation of performance is fostered by the arrangement of a centralised repository of information—the so-called data warehouse—focused on the aggregate data coming from different sources that is useful for the decision-making process. The storage model holds large volumes of real-time, complex, heterogeneous, structured, operational data generated in the different business

functions (accounting, IT, etc.). The creation of this archive is the starting point for future business intelligence solutions and the implementation of a Big Data warehouse, which is a more advanced computer system than those currently adopted and will allow integration and reorganisation of data from various sources attributable to three main categories: (i) information from person to machine; (ii) information from person to person (social networks); and (iii) information from machine to machine (IoT).

From the case study, it emerged that the adoption of innovative technologies for the acquisition and monetisation of all sources, both internal and external, and the subsequent construction of a shared platform first affected the risk management area, as it is important to capitalise on the information in the formulation of strategies and techniques for the management and coverage of risky events and to exploit possible opportunities. The involvement of the other functions (internal auditing and control of management and planning) came later, beginning a process of integration between the holistic and atomic levels—that is, between top management and operations. Through the evaluation of the interdependence and interaction of the individual functions within the processes, it is possible to examine the different factors that determine rising risks and, consequently, to adopt more efficient monitoring and anticipation policies for assessment, understanding and management.

In conclusion, the challenge for the banking sector is to import non-conventional technologies (IoT, business intelligence, Big Data and blockchain) that allow the processing of huge quantities of data quickly and accurately, which is useful not only in CRM, but also in cyber security, fraud detection and the optimisation of decision-making processes. A technological innovation must be accompanied by a cultural change and, in this case, the formation of teams composed of statistical, mathematical and technological skills and data scientists who can combine data analysis skills with functional skills to create automatic processes of value. This ongoing disruptive change necessarily affects people and involves the whole organisation, including IT, marketing, business and management control, strategic planning and customer service, to obtain significant advantages in terms of risk analysis, fraud prevention and advanced analysis of customer intelligence through the storage, organisation, management and operational use of large quantities of data; this will be part of a future evolution. The knowledge potentialities of BDA are therefore accompanied by a series of criticalities, starting with the risks of data confidentiality and progressing to organisational problems connected to the need to cooperate with those who can use the algorithms and reorganise internal information systems.

REFERENCES

Arena, M., Arnaboldi, M., Azzone, G. (2010), The organizational dynamics of enterprise risk management. Accounting, Organizations and Society, 35, 659-675.

Banarescu, A. (2015), Detecting and preventing fraud with data analytics. Procedia Economics and Finance, 32, 1827-1836.

Beasley, M.S., Pagach, D., Warr, R. (2008), Information conveyed in hiring announcements of senior executives overseeing enterprise-wide risk management processes. Journal of Accounting, Auditing and Finance, 23(3), 311-332.

Bhimani, A. (2009), Risk management, corporate governance and management accounting: Emerging interdependencies. Management Accounting Research, 20, 2-5.

Boscal, K.H.Y., Lai, I.K.W., Chan, S.K.C. (2010), Supply Chain Risk Management Model ERM Approach. 8th International Conference on Supply Chain Management and Information.

Broeders, H., Khanna, S. (2015), Strategic Choices for Banks in the Digital Age, McKinsey Global Institute Reports. pp1-7. Available from: https://www.mckinsey.com/industries/financial-services/our-insights/strategic-choices-for-banks-in-the-digital-age.

Chen, J., Tao, Y., Wang, H., Chen, T. (2015), Big data based fraud risk management at Alibaba. The Journal of Finance and Data Science, 1, 1-10.

Choi, T.M., Lambert, J.H. (2017), Advances in risk analysis with big data. Risk Analysis, 37(8), 1435-1442.

CoSO (2017), Enterprise Risk Management Aligning Risk with Strategy and Performance. CoSO.

De Loach, J.W. (2000), Enterprise-wide risk management. London: Financial Times-Prentice Hall.

Edwards, J.S., Taborda, E.R. (2016), Using the knowledge of management to give context to analytics and big data and reduced strategic risk. Procedia Computer Science, 99, 36-49.

Eisenhardt, K.M. (1989), Building theories from case study. Academy of Management Review 14(4), 532-550.

Elgendy, N., Elragal, A. (2014), Big Data Analytics: A Literature Review Paper. Switzerland: International Publishing. p214-227.

Ellul, A., Yerramilli, V. (2013), Stronger risk controls, lower risk: Evidence from U.S. bank holding companies. The Journal of Finance, 68(5), 1757-1803.

Floricel, S., Miller, R. (2001), Strategizing for anticipated risks and turbulence in large-scale engineering projects. International Journal of Project Management, 19, 445-455.

Florio, C., Leoni, G. (2017), Enterprise risk management and firm performance: The Italian case. The British Accounting Review, 49(1), 56-74.

Forest, H., Foo, E., Rose, D., Berenzon, D. (2014), Big Data. How it Become a Differentiatior. Passion to Perform, Deutsche Bank - Global Transaction Banking. pp1-28. Available from: https://www.cib.db.com/docs_new/GTB_Big_Data_Whitepaper_(DB0324)_v2.pdf.

Gandomi, A., Haider, M. (2015), Beyond the hype: Big data concepts, methods and analytics. International Journal of Information Management, 35, 137-144.

Gordon, L.A., Loeb, M.P., Tseng, C.Y. (2009), Enterprise risk management and firm performance: A contigency perspective. Journal of Accounting Public Policy, 28, 301-327.

Grace, M.F., Leverty, J., Phillips, R., Shimpi, P. (2015), The value of investing in enterprise risk management. Journal of Risk and Insurance, 82(2), 289-316.

Hasnat, B. (2018), Big data: An institutional perspective on opportunities and challenges. Journal of Economic Issue, 52(2), 580-588.

Hossein, H., Xu, H., Emmanuel, S.S. (2018), Digitalisation and big data mining in banking. Big Data and Cognitive Computing, 2(3), 18.

Hu, D., Zhao, J.L., Hua, Z., Wong, M.C. (2012), Network-based modelling and analysis of systemic risk in banking system. MIS Quarterly, 36(4), 1269-1291.

IBM. (2014), Operational Risk Management in the World of Big Data. IBM Software. Business Analytics. United States: IBM. p1-12.

Idris, A., Norlida, A.M. (2016), Influence of enterprise risk management success factors on firm financial and non-financial performance: A proposed model. International Journal of Economics and Financial Issues, 6(3), 830-836.

ISO 31000. (2018), Risk Management e principles and Guidelines. Geneva: International Organization for Standardization.

Kathuria, A. (2016), Impact of big data analytics on banking sector. International Journal of Science, Engineering and Technology Research, 5(11), 3138-3141.

Krishna, D. (2016), Big data in risk management. Journal of Risk Management in Financial Institutions, 9(1), 46-52.

Lackovic, D.I., Kovska, V., Lakovic, V.Z. (2016), Framework for Big Data Usage. Risk Management Process in Banking Institutions. Central European Conference on Information and Intelligent System. p49-54.

Liebenberg, A.P., Hoyt, R.E. (2003), The determinants of enterprise risk management: Evidence from the appointment of chief risk officers. Risk Management and Insurance Review, 6(1), 37-52.

Liebenberg, A.P., Hoyt, R.E. (2011), The value of enterprise risk management. The Journal of Risk and Insurance, 78(4), 795-822.

Manyika, J., Chui, M., Brown, B., Bughin, J., Dobbs, R., Roxburg, C., Byers, A.H. (2011), Big Data: The Next Frontier for Innovation, Competition and Productivity, USA, McKinsey Global Institute Reports. Available from: https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/big-data-the-next-frontier-for-innovation.

Mohamad, S.H., Rashila, R., Marwan, Y.I.M., Azzam, I.R. (2015), Reputation risk and its impact on the Islamic banks: Case of the Murabaha. International Journal of Economics and Financial Issues, 5(4), 854-859.

Muller, O., Fay, M., Vom Broke, J. (2018), The effect of big data and analytics on firm performance; an econometric analysis considering industry characteristics. Journal of Management Information System, 35(2), 488-509.

Munesh, K., Mittal, P. (2014), Big data: A review. International Journal of Computer Science and Mobile Computing, 3(7), 106-110.

Navak, N., Akkiraju, R. (2012), Knowledge Driven Enterprise Risk Management. California: Annual SRII Global Conference.

Nocco, W.B., René, M.S. (2006), Enterprise risk management: Theory and practice. Journal of Applied Corporate Finance, 18(4), 8-20.

Ozkose, H., Ari, E.S., Gencer, C. (2015), Yesterday, today and tomorrow of big data. Procedia Social and Behavioural Sciences, 195, 1042-1050.

Radmehr, E., Bazmara, M. (2017), A survey on business intelligence solutions in banking industry and big data applications. International Journal of Mechatronic, Electrical, Computer Technology, 7(23), 3280-3329.

Rasmussen, J. (1997), Risk management in a dynamic society: A modelling problem. Safety Science, 27(2/3), 183-213.

Ravisankar, P., Ravi, P., Raghava, R.G., Bose, I. (2011), Detection of financial statement fraud and feature selection using data mining techniques. Decision Support Systems, 50(2), 491-500.

Saggi, M.K., Jain, F. (2018), A survey towards an integration of big data analytics to big insights for value-creation. Information Processing and Management, 54, 758-790.

Sagiroglu, S., Sinanc, D. (2013), Big Data: A Review. San Diego, CA, USA: International Conference on Collaboration Technologies and Systems. p42-47.

Srivastava, U., Gopalkrishnan, S. (2015), Impact of Big Data Analytics on Banking Sector: Learning for Indian Banks. Procedia Computer Service, No. 50. 2nd International Symposium on Big Data and Cloud Computing, 50, 643-652.

Vasarhelyi, M.A., Kogan, A., Tuttle, B.M. (2015), Big data in accounting: An overview. Accounting Horizon, 29, 381-396.

Warren, J.D. Jr., Moffitt, K.C., Byrnes, P. (2015), How big data will change accounting. Accounting Horizon, 29, 397-407.

Woods, M. (2007), Linking risk management to strategic controls: A case study of Tesco plc. International Journal of Risk Assessment and Management, 7, 1074-1088.

Yin, R.K. (2014), Case Study Research: Design and Methods. Thousand Oaks, CA: Sage Publications.