The Roles of Big Data in the Decision-Support Process: An Empirical Investigation

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Abstract. The decision-making process is marked by two kinds of elements: organizational and technical. The organizational elements are those related to companies' day-to-day functioning, where decisions must be made and aligned with the companies' strategy. The technical elements include the toolset used to aid the decision making process such as information systems, data repositories, formal modeling, and analysis of decisions. This work highlights a subset of the elements combined to define an integrated model of decision making using big data, business intelligence, decision support systems, and organizational learning all working together to provide the decision maker with a reliable visualization of the decision-related opportunities. The main objective of this work is to perform a theoretical analysis and discussion about these elements, thus providing an understanding of why and how they work together.

Keywords: Decision support · Decision-making process · Big Data · Business Intelligence (BI) · Decision Support System (DSS) · Organizational learning

1 Introduction

Organizations need to use a structured view of information to improve their decision-making process. To achieve this structured view, they have to collect and store data, perform an analysis, and transform the results into useful and valuable information. To perform these analytical and transformational processes, it is necessary to make use of an appropriate environment composed of a large and generalist repository, a processor core with the appropriate intelligence (Business Intelligence [BI]), and a user-friendly interface.

The repository must be filled with data originating from many different kinds of external and internal data sources. These repositories are the data warehouses (generalists) and data marts (when considering a specific company activity or sector), and most recently, Big Data.

The Big Data concept and its applications have emerged from the increasing volumes of external and internal data from organizations that are differentiated from other databases in four aspects: volume, velocity, variety, and value. Volume considers the data amount, velocity refers to the speediness with which data may be analyzed and processed,

variety describes the different kinds and sources of data that may be structured, and value refers to valuable discoveries hidden in great datasets [1].

Big Data has the potential to aid in identifying opportunities related to decision in the intelligence phase of Simon's [2] model. In some cases, the stored data may be used to aid the decision-making process. In this context, the term "intelligence" refers to knowledge discovery with mining algorithms. In this way, Big Data use can be aligned with the application of Business Intelligence (BI) tools to provide an intelligent aid for organizational processes. The data necessary to obtain the business perceptions must be acquired, filtered, stored, and analyzed after the available data are heterogeneous and in a great volume. The processes of filtering and analysis of the data are very complex, because of that it is necessary the use BI strategies and tools.

The main proposal of the present study is to develop an investigation that describes the roles of Big Data, and BI in the decision-making process, and to provide researchers and practitioners with a clear vision of the challenges and opportunities of applying data storage technologies so that new knowledge can be discovered.

The sequence of this work is as follows. Section 2 provides a background for Big Data and some of its applications. Section 3 introduces the concept of DSS. Section 4 conceptualize BI and presents its organizational and technological components. Section 5 presents a scheme for the integration between Big Data, BI, decision structuring and making process, and organizational learning. Section 6 contains a discussion about the integration perspective of the decision-making process, according the scheme presented in Sect. 5. Finally, the conclusion presents the limitations of this study and highlights the insights this work has gained.

2 Big Data

With data increasing globally, the term "Big Data" is mainly used to describe large datasets. Compared with other traditional databases, Big Data includes a large amount of unstructured data that must be analyzed in real time. Big Data also brings new opportunities for the discovery of new values that are temporarily hidden [3].

Big Data is a broad and abstract concept that is receiving great recognition and is being highlighted both in academics and business. It is a tool to support the decision-making, process by using technology to rapidly analyze large amounts of data of different types (e.g., structured data from relational databases and unstructured data such as images, videos, emails, transaction data, and social media interactions) from a variety of sources to produce a stream of actionable knowledge [4].

After the data is collected and stored, the biggest challenge is not just about managing it but also the analysis and extraction of information with significant value for the organization. Big Data works in the presence of unstructured data and techniques of data analysis that are structured to solve the problem [1].

A combination called the 4Vs characterizes Big Data in the literature: volume, velocity, variety, and value [5]. Volume has a great influence when describing Big Data as large amounts of data are generated by individuals, groups, and organizations. Zikopoulus et al. reports that the estimated data production by 2010 was about 35 zettabytes [6].

The second item, velocity, refers to the rates at which Big Data are collected, processed, and prepared—a huge, steady stream of data that is impossible to process with traditional solutions, For this reason, it is important to consider not only "where" data are stored but also "how" they are stored.

The third item, variety, is related to the types of data generated from social sources, including mobile and traditional data. With the explosion of social networks, smart devices, and sensors, data have become complex because they include semi-structured and unstructured information from log files, web pages, index searches, cross-media, e-mail, documents, and forums.

Finally, the value can be discovered from the analysis of the hidden data, so Big Data can provide new findings of new values and opportunities to assist in making decisions. However, management of this data can be considered as a challenge for organizations [1].

In order to demonstrate the differentiation between Big Data and Small Data, we analyzed them using five main characteristics: goals, data location, data structure, data preparation, and analysis, in Table 1.

Importantly, relational databases are not obsolete, on the contrary, they continue to be useful to a number of applications. In practice, how larger a database becomes, the higher the cost of processing and labor, so it is necessary to optimize and add new solutions to improve storage providing greater flexibility.

For the purpose to better understand the impact of science and Big Data solutions, the applications and Big Data solutions in the following different contexts will be presented: education, social media and social networking, and smart cities.

Grillenberger and Fau used educational data to analyze student performance [7]. Their learning styles were also clarified by the use of Big Data in conjunction with teaching strategies to gain a better understanding of the students' knowledge and an assessment of their progress. These data can also help identify groups of students with similar learning styles or their difficulties, thus defining a new form of personalized learning resources based on and supported by computational models.

Big Data has created new opportunities for researchers to achieve high relevance when working in social networks. In this context, Chang, Kauffman and Kwon used communications environments to discuss the causes of the paradigm shift and explored the ways that decision support is researched, and, more broadly, applied to the social sciences [8].

In the context of a smart city, Dobre and Xhafa provide a platform for process automation collection and aggregation of large-scale information. Moreover, they present an application for an intelligent transportation system [9]. The application is designed to assist users and cities to resolving the traffic problems in big cities. The combination of these services provides support for the application in intelligent cities that can, benefit from using the information dataset.

The value of Big Data is driving the creation of new tools and systems to facilitate intelligence in consumer behavior, economic forecasting, and capital markets. Market domination may be driven by which companies absorb and use the best data the fastest. Understanding the social context of individuals' and organizations' actions means a company can track not only what their customers do but also get much closer to learning why they do what they do.

Table 1. Comparison of main characteristics of Big Data and Small Data.

Aspects	Big Data	Small Data
Goals	In general, they are projected from a predetermined goal and have a greater level of flexibility, considering the context of the problem. For example, the market scenario analysis to identify forms to accelerate the sales can be considered	They are generally designed to answer a specific question and control in a particular context. For example, inventory control, get only information concerning the entry and exit of goods, is not always done interaction between customer and supplier, acting on the basis of current market
Data location	The location normally aggregates data spread across different media, which can be in several Internet servers. The architecture consists of a distributed computing where multiple servers work together to store and process information. High power scalability, low cost of implementation	In general, the data come from the internal organization and the data files. For example, working with spreadsheets results in great increases on internal control
Data structure	The structure is usually able to absorb unstructured data (e.g., free text documents, images, movies, sound recordings, and physical objects). In others words, Big Data is just to be able to work with many variables simultaneously, as reading and rendering images in minimal time and very efficiently. For example, smart city applications, using real-time information to describe the traffic of a big city	The structure usually contains structured data. Data are represented by uniform records in an orderly spreadsheet. For example, the enterprise resource planning (ERP) that are systems that have a pre-defined architecture and their records represents a structured way to work with data within organizations
Data preparation	In general, the data come from different sources and are prepared by several users. People who use the data rarely are the ones who prepared. In this context, different people in different organizational roles contributes to disseminate information	In many cases, the data users prepare their own data for their own purposes. For example, presenting the results according to a specific context to which the user is located
Analysis	Analysis is usually done in incremental steps. The data are extracted, revised, normalized, processed, visualized, interpreted, and then analyzed with different methods. For example, complex techniques of data analysis combining data mining and artificial intelligence	In most cases, all the data for the project can be analyzed all at once. In this case, the structure is pre-defined and based on the specific context. Also are used Structured Query Language (SQL) combined with appropriate programming languages to create procedures to mining, process and analyze the data

Sources: [4, 1].

To date, for the use of Big Data, a modern infrastructure is needed to overcome the limitations related to language and methodology. Guidelines are needed in a short time in order to deal with such complexities, as different tools and techniques and specific solutions have to be defined and implemented. Furthermore, different channels through which data are collected daily increases the difficulties of companies in identifying which is the right solution to get relevant results from the data path. In this context, the technology of BI and DSS will be presented.

3   Decision Support Systems (DSS)

Information and knowledge are the most valuable assets for organizations' decision-making processes and need a medium to process data into information loaded with value and relevance for use in organizational processes. Information Systems (IS) represent these media. Specifically focused on the decision-making process, the DSS work for the processing, analyzing, sharing, visualizing of important information to aid in the process of knowledge aggregation and transformation, and thereby improve the organizational knowledge.

DSS are IS designed to support solutions for decision-making problems. The term DSS has its origin in two streams: the original studies of Simon's research team in the late 1950s and the early 1960s and the technical works on interactive computer systems by Gerrity's research team in the 1960s [10]. In a more detailed definition, DSS are interactive, computer-based IS that help decision-makers utilize data, models, solvers, visualizations, and the user interface to solve semi-structured or unstructured problems. DSS are built using a DSS Generator (DSSG) as an assembling component [11].

DSS have a strict link with intelligence-design-choice model, but acting with more power in the choice phase [2]. Their main objective is to support a decision by determining which alternatives to solve the problem are more appropriate. Although the choice is made by a human agent (a manager, treated as a decision-maker within this process), the DSS role is to provide a friendly interface where the agents can build scenarios and simulate and obtain reports and visualizations to support the decisions [12].

This kind of system has a set of basic elements that includes a data base and a model base with their respective management, the business rules to process data according a chosen model (e.g., the core of the system), and a user interface [10]. Data and model bases and their respective management systems allow for business rules in processing data according to a model to formulate the possibilities of solutions for the problem.

4   Business Intelligence

An organization's decision-making process begins with the intelligence phase of Simon's [2] model. In this phase, the perception is made that there is a problem to be solved in the future by applying problem structuring methods. Also in this phase, the tools of BI may be used to support the organization's discovery of opportunities for decision-making by, providing advanced analytics and assuring data integration [13].

So, besides the problem solving, decision opportunities can be added to the set of benefits that BI can bequeath to the scope of decision support.

The definition of BI can be expressed in two ways: in a holistic organizational decision-making approach and in the technical point of view [14]. Similarly Handzic, Ozlen and Durmic presents two kinds of concepts for BI: one centered on data analytics supporting decision-making processes in organizations and the other focused on tools and technologies for data storage and mining for knowledge discovery [15]. This study will adopt the strategy of considering BI as a system that includes both organizational and technical perspectives that provide the information needed to perform an analysis the aid the generation of decision opportunities, the decision-making process, and the organizational learning process.

Regarding this definition, BI covers all the processes involved in extracting valuable and useful information from the mass of data that exists within a typical organization to support the decision-making process. Business Intelligence Systems (BIS) are those that makes use of a combined process involving IT solutions and business experts' knowledge on the operation of business, integration and organizational management obtained as a result of intelligent decision-making [16, 17].

According to Azma and Mostafapour, there are two main features of data: the organizational learning process and the smart processing of data [17]. The organizational learning includes the discovery of new knowledge and dissemination of this knowledge to those who need it. The smart processing includes analyzing and assessing the information, providing decision support to ensure the aligning of the future performance of the organization with the planning, and providing knowledge feedback about the involved processes to be combined with pre-existing (explicit) knowledge.

Chang, Hsu and Shiau set up BI like both a product and a process. From the process perspective, the main goal of BI is to aid the decision-making process and reduce the time spent on the decision [18]. For this to occur, it is necessary that all the sets of basic components be defined and implemented. From the product perspective, the BI is the IT component that contains the referred to set of basic components and that can be used as the core engine of DSS to generate analytics for managers as the decision-makers.

From an organizational perspective, BI is part of a decision environment that combines both technology sets and human capacities in order to obtain decisions strategically aligned with the organization's planning. This is the holistic organizational decision-making approach that Işık, Jones and Sidorova mentioned and that still includes BI capabilities such as data quality, integration with other systems, user access, system flexibility, and risk management support [14]. These authors conceptualized the first three capabilities as technological BI and the last two as organizational BI.

Handzic reinforces the Knowledge Management (KM) and organizational learning point of view for BI, considering some organizational aspects focused on human interaction which the authors called socio-technical perspective: organizational culture, leadership, and measurement for successful implementations [19]. Figure 1 shows this perspective.

Considering the definitions by Handzic [19] and Grünwald and Taubner [20] leads to understanding that the information evolutionary scale is made possible through a technical toolset that supports the necessary transformations between the points of the
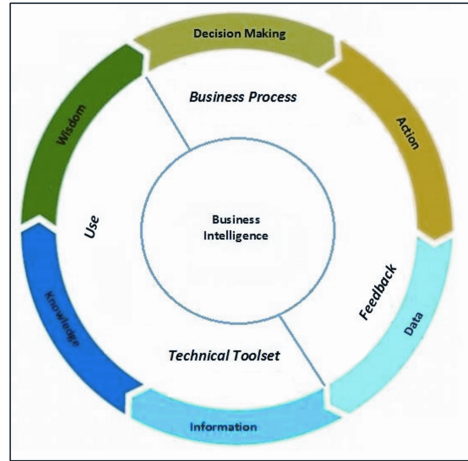
Fig. 1. Business process support using BI. Source: Adapted from [20].

scale (since data is until wisdom), including elements of Artificial Intelligence (AI). The business process, in turn, includes the decision-making process and the action to implement the decision. In Fig. 1, the combination of BI, business process, and the technical toolset could be understood as the elements that define a DSS, because they represent information transformations followed by their application in decision-making and the provision of feedback to initiate a new cycle of information transformation.

The works cited previously describe intrinsic issues to Big Data and highlight the use of BI alone. The differential of our proposal is to get an integrated view of the technologies involved, aggregating value to the decision-making process.

5   Integrated Model for Decision-Making Process, Big Data, and BI Tools

Simon's decision model summarizes the decision-making process into three phases, as introduced previously. Each phase this model is susceptible to the use of methods and tools from organizational and technological perspectives. The organizational perspective may use Problem Structuring Methods (PSM); Multi-criteria Decision Aid (MCDA); and KM techniques such as brainstorming, communities of practice, best practices, narratives, yellow pages, peers assistance, and knowledge mapping. These methods and techniques aids in the knowledge elicitation of the actors involved in the decision-making process, thus contributing to identify the necessary expertise necessary for solve the specific problem in question, as in the case of PSM and KM techniques, or acting to provide recommendations to solve this problem, as in the case of MCDA.

Technological tools involve data repositories (e.g., data warehouses and data marts) filled with data from public sources, BI or even AI and Problem Solving Methods (PSolM) originated from Knowledge Engineering (KE) (e.g., CommonKADs and Methodology and Tools Oriented to Knowledge-Based Engineering Applications [MOKA]).

These tools are important elements that contribute to store, access and analyze information, discovering and sharing knew knowledge in databases and even supporting the application of the organizational perspective's methods and technics.

The main purpose of this work is the integration of the decision-making process with some of these tools presented in Fig. 2, considering the perspective of the predictive approach to decision-making. In this perspective, the use of methods to structure decision problems and suggest alternatives to choose from is an important issue and an efficient way to support the DSS design and development. Combined with the predictive approach, this process makes use of BI tools to provide domain information to aid all the phases of the process.

Fig. 2. Integrated model of the decision-making process.

It is noteworthy that some of these elements are framed within the phases of Simon's model. In the phase of intelligence, by making use of Big Data powered by internal and external data sources, organizations can make use of BI strategies and tools to aid in identifying relevant information, and then the generation of decision opportunities occurs.

The function of the design phase is to provide a methodology to aid the choice of the alternatives based in what was defined in the problem structuring process during the intelligence phase. This design must also be incorporated into this methodology, as formal aspects related to the method or model that are defined according the problems identified during the problem structuring process. The development of DSS has made

the use of this model viable by allowing the decision-makers, through a friendly and easy-to-use interface, to perform a series of configurations.

In the final phase of choice, the decision-makers will use the results generated by DSS to complete the decision-making process with the choice of one, or a set of, alternatives, that will then be implemented by the organization.

All these processes produce new knowledge to be combined with previous knowledge about the domain of the problem. This new knowledge will provide feedback to power the Big Data so that it can be used as necessary, thus fulfilling its role in the organizational learning process.

Each element of the integrated model is described as follows:

(a) *Content acquisition through public and private organizational data sources:* This is mainly concerned with the collection, storage, and integration of relevant information necessary to produce a content item. In the course of this process, information is being pooled from internal or external sources for further processing. Big Data incorporates different types of sources, including text, audio, video, social networks, images, time forecasting, etc. Strictly, the main purpose of this element is none other than the data acquisition from Big Data to use in decision-making process.

(b) *Intelligence:* The whole world is producing a great amount of data. Thus, this is relevant as Big Data obtains its value from three of the 4Vs: volume, variety, and velocity. In this phase, aggregated values from stored data have a fundamental role for the creation of opportunities and alternatives once the data are analyzed. Moreover, in this context it is important to highlight the importance of data visualization. For example, in a spreadsheet is difficult to identify trends in data. However, the use of graphics and images improve the perception for the data analysis helping a faster recognition of trends or patters and improving the capacity of the data analyst to perform his work. Based on the visualization provided by the elements that composes Big Data concept, corrective actions can be done in case of deviations and negative trends. Therefore, in the intelligence phase the concept of Big Data should not be analyzed only with volume, but can improve the ability to view this data, filtering a large volume of data in different contexts of information. Visualization techniques are now extremely important for the generation of value of the concept of Big Data. After all, Big Data is not a concept just about data, but we can extract insights and intelligence and visualization is the fundamental key to the decision-making process. The intelligence represents the capacity to aggregate value to acquired data in order to obtain relevant information, applicable in the organizational problem solving. These information should be capable of contextualize with internal and external phenomena of the organization, ensuring the other following elements the necessary power of action to satisfactorily contribute to resolve the problem.

(c) *Opportunities and alternatives generation:* This is the process of creating alternatives, which is not a trivial task. It starts with dataset analysis that enable decision-makers to obtain a global view of the process. Then, from the analyses performed through BI tools with Big Data content, decision-makers pro-actively create opportunities and generate opportunities to solve the decision problem. This phase also

works for the definition of the criteria, which the decision-makers will use to judge or evaluate each alternative.

(d) *DSS:* With the opportunities identified and having the criteria and alternatives to evaluate, DSS may be implemented according a decision problem that will predict which method is the most adequate. DSS will act in helping decision-makers in obtaining an indication or a recommendation of alternatives to choose from that will be implemented to solve the problem.

(e) *Implementation of decision:* After a choice is made, alternatives will be implemented in organizations to actively solve the identified problem.

As a last element, the Organizational Learning says respect to all these processes' elements generating important knowledge about the decision problem. This knowledge may be captured, registered, and stored in a knowledge repository to provide organizational memory about the problem domain and will be available for use at any time. The standard flow of this new knowledge, after the implementation of the chosen action, runs to private (or internal) data sources, e.g., a base of managerial practices.

6 Discussion

Knowledge extracted adequately from Big Data aggregates the value that decision-makers use to identify a decision opportunity. This work provided theoretical evidence to corroborate the idea that the perspective of historical data combined with decision-makers' knowledge and experience, formal problem structuring, and use of decision methods or models may make the decision-making process more robust and more reliable.

Generally, companies use the descriptive approach to make decisions, by performing an analysis based only on historical data. The focus solely on the past makes it difficult to concentrate on new strategies for the future. The proposition of the present work also considers this descriptive approach, but it recognizes the value of the predictive approach in order to provide recommendations to solve a decision problem, based on decision-makers' knowledge and judgment, and information technology: Big Data, BI, and DSS.

The Big Data study performed here started with the analysis of the data's influence over the decision-making process by ensuring that decision-makers can discover opportunities to act problem solving.

The main contributions of the theoretical approach presented here are (i) develop a perspective that combines the decision-making process, Big Data, BI, DSS, and organizational learning and (ii) use the concept that Big Data works as a data provider over which may be applied BI techniques and tools may be applied mainly in supporting the discovery of opportunities for a decision.

Decision-makers, when preparing for making a decision, incorporate their knowledge and discernment along with an organizational learning process that will help them to create an organizational memory that provides knowledge generated through the process for later use. Thus, beyond technological toolsets and decision-making and methodologies, the process described here takes into account the subjective characteristics linked to the decision-makers' perceptions, experiences, and personalities.

The use of Big Data provides to managers the possibility to explore both internal and external information, not only identifying a decision problem but also having as proposal the potential to increase de intelligence power within the decision-making process.

7 Conclusion

The increasing amount of data that arrives at organizations accumulate through electronic communication is amazing, in that not only has the volume of the data change, but also the variety of information collected in through several communication channels ranging from clicks on the Internet to the unstructured information from social media. In addition, the speed at which organizations can collect, analyze, and respond to information in different dimensions is increasing.

Big Data has become a generic term, but in essence, it presents two challenges for organizations. First, business leaders must implement new technologies and then prepare for a potential revolution in the collection and measurement of information. Second, and most important, the organization as a whole must adapt to this new philosophy about how decisions are made by understanding the real value of Big Data.

Organizations must understand the role of the Big Data associated with decision-making, with the emphasis on creating opportunities from these decisions, because we live in a world that is always connected, and where consumer preferences change every hour. Thus, analysts can check multiple communication channels simultaneously and trace certain profiles or decider behaviors.

The main contribution of this work is to promote the integrated view of Big Data, BI and DSS inside the context of decision-making process, assisting managers to create new opportunities to resolve a specific problem.

The crucial point is to look widely for new sources of data to help make a decision. Furthermore, Big Data not only transforms the processes of management and technology but it also promotes changes in culture and learning in organizations.

Ultimately, Big Data can be very useful if used adequately in the decision-making process, but just its use will not guide the decision itself and it will not generate alternatives or predict the results. For this, the participation of decision-makers is essential, as their experience and tacit knowledge are necessary to aggregate value over information and the possible knowledge stored.

From this initial study, where the idea of get an integrated view of all these elements as decision-making tools, we can create a set of perspectives to apply in future researches, as example a detailed exploration focused on each phase of the model. Other ideas: semantic exploration of Big Data applied to decision problems structuring, direct integration between Big Data and BI tools to fulfil organizational repositories providing data to the information systems.

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