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Knowledge data extraction for business intelligence

A design science research approach

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Abstract

The application of *Business Intelligence* systems can be seen as a business strategy and development, which integrates a comprehensive set of services to provide relevant corporate information in strategic and operational decision-making, and to increase the corporation's competitiveness. For the successful implementation of a *Business Intelligence* System in an organization, it is necessary to use well-defined processes and business rules. The purpose of this article is to present and explore a set of tools and practices for extracting and exploiting *Big Data* sources. The result of this research approach aims to define a set of indicators and *dashboards* to improve the organization's business management and intelligence.

Keywords: Business Intelligence, Big Data, Data Wharehouse, Data Mining, Knowledge Data Discovery, Design Science.

1. Introduction

We live today in the "digital information era" and its ubiquity, which may lead us to assume that information is virtually available to everyone, anytime and from anywhere. Thus, with globalization contributing to increased competitiveness, organizations are forced to constantly change, to manage a large amount of data generated daily and which are essential to support decision-making. There is also a need to consider the competitiveness between organizations, where the awareness that data represent an essential source for the production of necessary information is becoming ever greater [19][6][7].

Computer applications have allowed organizations to have quality control over data, generate relevant indicators to be provided to managers about the organizations business, preparing them to design forecast scenarios more effectively

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and efficiently. Consequently, organizations are becoming increasingly dependent on the use of *Business Intelligence* (BI) applications to extract, process and organize the necessary data.

Given the new technologies that are being implemented in organizations, they are forced to consider as a decisive factor the continuous training of users for the adaptation and analysis of information, at the risk of delaying, or even losing, the growing race to provide updated and essential information for any decision process [9][23].

From the study carried out based on scientific areas, it is possible to affirm that there are new ways to evaluate data extraction tools for BI and to help users in the design of organized and quality information for organizations [2][23].

The objective of the work is to contribute to the development of a conceptual model that allows to serve as a guide for the extraction and exploration of data from *Data Warehouses* associated with BI systems, suitable for users and organizations to improve the quality of information, obtain the knowledge necessary for decision making.

The article is structured as follows: the next section frames BI systems in support of strategic management; the third section proposes the methodological approach; the fourth section presents a conceptual BI model for the organization; finally, the last section presents the conclusions.

2. Literature Review

The development of the work fits into the BI systems environment, in accordance with the emergence of new technologies such as: *Cloud Computing*, *Web Data*, *Big Data Warehouse*, among others, which leads to a need to explore and provide tools that allow users to users and companies develop analysis activities from the extraction and exploration of data effectively and efficiently for business development.

To identify the relevant procedures for extracting knowledge from data for the design of BI systems, a review of the literature published in the last 20 years was carried out, following the process presented in figure 1. The decision that led to restricting the review to this period is mainly related to the fact that the BI systems research and development is dependent on technological support, which in recent years has evolved considerably.

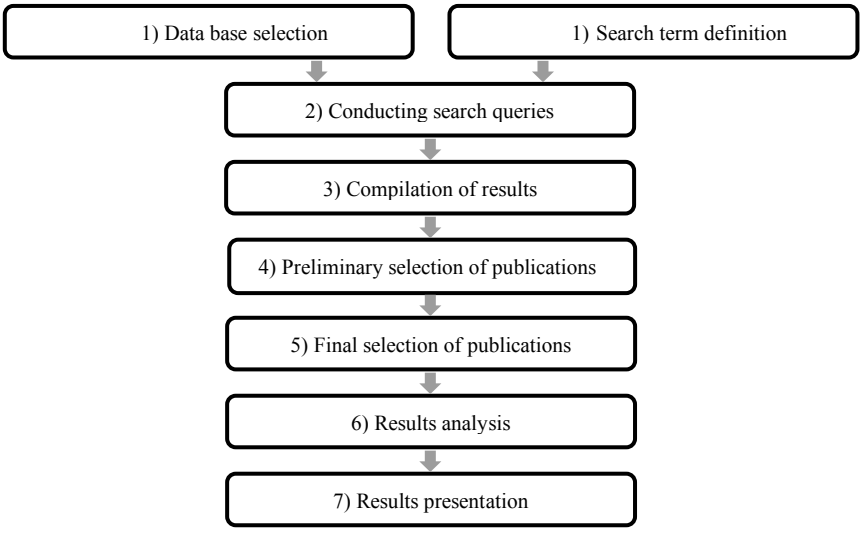

Fig. 1. Literature review research method.

In the first stage (step 1), the databases to carry out the research were selected, including the *Web of Knowledge*, *Scopus*, *ScienceDirect*, *ResearchGate* and *Google Scholar*, as they bring together a very comprehensive set of references in the field, and academically recognized. The search expressions to be used were also defined: "*Business Intelligence*", "*Data Knowledge Extraction*", "ETL", "*Integration Services*", "*Data Warehouse*", "*Analysis Services*", "OLAP (*On-Line Analytical Processing*)", "KDD (*Knowledge-Discovery in Databases*)" and "*Data Mining*". In the second stage (step 2), several searches were carried out with the terms and expressions previously defined.

The selection and search activity resulted in several publications that, once compiled (step 3), were analysed using the title, abstract and keywords as reference (step 4). When it was not possible to identify the relevance of the publication for the study only through the initial reading, the full reading was carried out (step 5). Finally, from the full reading of the articles, those that presented methodologies and proceedings for extracting data for BI systems were identified, which were then analysed (step 6) and presented (step 7).

Data Knowledge Extraction

The purpose of extracting knowledge from big sources of data is the analysis of structured (and semi-structured, and unstructured) data representing business objects, from *Data Warehouses* associated with BI systems [9][23]. After getting the data, it is organized in cubes (OLAP components) using the concept of multidimensional view to allow its exploration through *dashboards* and reports, and to provide answers to the analyses carried out on business indicators, which lead us to business intelligence tasks.

Business Intelligence

The success of organizations in an increasingly technological world lies in making strategic decisions in real time. In answer to this need, the concept of BI comes up, which match architectures, data storage, analytical tools, computer applications, and methodologies that transform data into useful and relevant information to support decision-making, enhancing business success [9][23][20][15][7][14].

BI is the meeting point between business, management and information technology. It is possible for organizations to get aggregated and structured information from large volumes of data and different software solutions, develop performance indicators and *dashboards* with real-time information, as well as enhance their customers' knowledge to increase their satisfaction and empower its employees, such as executives, managers and analysts, to make quality decisions in real time. In this sense, there are reasons to invest in BI, where organizations can end management by instinct and gain efficiency and effectiveness, know the behaviour of customers, analyse the past, observe the present, predict the future of the business and anticipate competition [9][23][11][2][5].

BI systems improve the availability and quality of information [18][1][16]. In this sense, BI systems include *Data Warehouses*, which are repositories of organizational information, as well as OLAP data analytical processing systems and *Data Mining* mechanisms. In other words, the first ones provide a multidimensional analysis of the data and the second ones are used to extract knowledge, identifying standards and predictive models in the data.

Business Intelligence Architecture

Figure 2 shows the BI architecture with the following parts: Data sources, (ETL - *Extract, Transform, Load*), *Data Warehouse* and *Data analysis*.

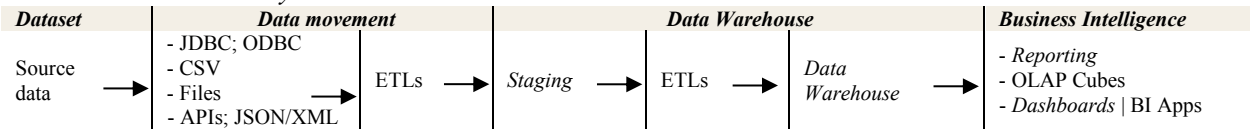

Fig. 2. BI process architecture

The presentation of a layered architecture allows to identify the implementation phases and technologies needed to design BI. The architecture consists of five layers, corresponding respectively to the environments: data sources, data movement, *Data Warehouse*, server environment and the business analysis environment:

- In the **data source layer** are the data sources that support the system. *Data sources* can be intern and extern to the organization, such as relational databases, Excel files, CSV (*comma-separated-values*) files, among others, in which the data originates from the normal operational process of the company, being recorded operating systems OLTP (*On-Line Transactional Processing*).

- The next layer represents the **movement of data** through the ETL process (*Extract, Transform, Load*), which allows the management of data extraction, with the integration of systems that have different technologic platforms, such as base management systems data, operating systems, and different communication protocols [8]. The transformation phase, according to the authors Golfarelli & Rizzi [10], should be divided into two distinct phases: Cleaning and Transformation of the extracted data, in order to get correct and consistent data, considering the activities as the definition of the granularity of fact tables and dimension tables. In the loading phase, the extracted and transformed data is inserted into the dimensional structures, to be accessed by end users and system applications. This phase includes loading dimension tables and fact tables [8]. Golfarelli & Rizzi [10] also consider the refresh and update techniques. In which, the refresh technique allows the replacement of old data with current data, and the refresh technique is the addition of new records, without modifying or deleting the old data.
- In the next layer is the ***Data Warehouse*** environment. It is an organizational data repository, integrated from the ETL process and forms the main base for data analysis activities. The objective is to organize the information in a multidimensional way, facilitating the exploration of this information. According to Caldeira [4], the *Data Warehouse* has to do with the autonomy of the user, who is the active agent in data exploration.
- The **business analysis layer** from the server environment, allows you to work with data, accessing the organizational *Data Warehouse*, using several techniques, such as OLAP and *Data Mining*, to generate relevant information for decision making and make it available to managers. According to Turban et al [23] the main structure in OLAP is based on "cubes", which is a multidimensional data structure to allow analytic queries with greater speed and efficiency. Using OLAP, the user is allowed to browse the data stored in the *Data Warehouse* and carry out several types of research, whose navigation groups *drill-down/up, roll-up, slice, dice and pivot* operations. In the framework of the construction of a Cube-type application, it is verified that what is presented to the user is the information in a cubic view. As can be seen through in figure 3, it is the output of the OLAP servers, in which the dimensions and facts of *Data Warehousing* are directly mapped to this application, allowing the user to change its edges and segments, according to its data search needs.

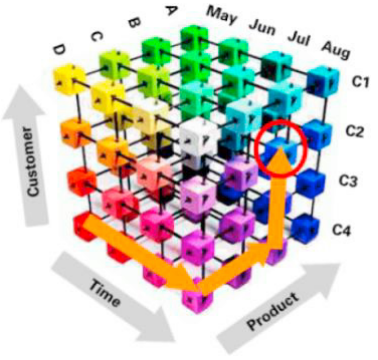

Fig. 3. Cube application system (Source: Oracle Corporation)

Data Warehouses store the organization's historical and structured data to generate information and knowledge about the business process. The data gathered in the *Data Warehouse* comes from different sources and formats, being defined in a coherent and uniform way [25][3][17].

The objective of the *Data Warehouse* is the organization of information in a multidimensional way, allowing at the same time the ease and optimization of queries and data analysis [9][4].

The dimensional model used by *Data Warehouses* offers several advantages to a BI system, such as: keeping the information history; good quality information; single repository to access information; information aggregated into hierarchies; consolidated information and optimization in queries; competitive advantage, with timely availability of information to managers, immediately identifying market requirements and risks in the decision process; simplicity, providing a simple picture of the organization's reality; ease of use in accessing data, with an intuitive graphical interface that facilitates the analysis of information stored by users in the *Data Warehouse*; quantitative values (KPIs), which allow comparison and analysis over periods of several years [26][3][13].

The organization of data in the *Data Warehouse* is done according to the multidimensional model that can be presented in different ways. However, the simplest and most intuitive way is through the *Star Schema Model* that contains a table of facts and a set of dimensional tables, as shown in figure 4.

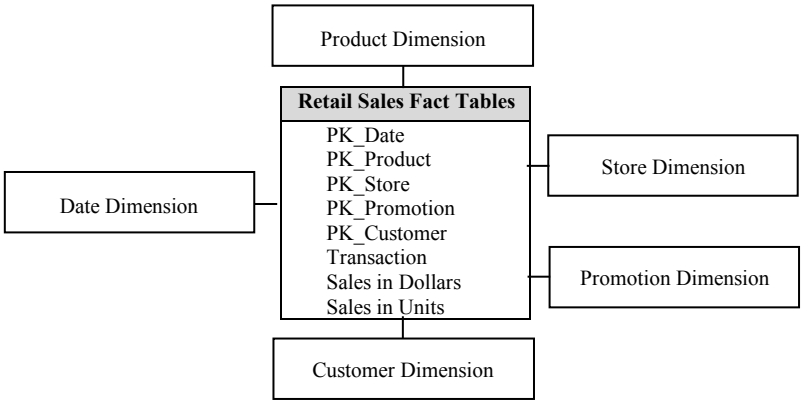

Fig. 4. *Star schema* and dimension tables [13]

The figure 4 presents a central table, designated as the fact table with the primary keys of the size tables and performance measures representing the main events of the organization. It can be, for example, the quantity of a product sold, the price, among other attributes. The fact table must have its own *primary key* (PK) that links to the *foreign keys* (FK) of the other tables.

Dimension tables are integral parts of the fact table and are related to the characteristics of the business process. These questions ask questions such as "who", "what", "where", "when", "how" and "why" that are closely associated with the event [13].

ETL process

The ETL process shown in figure 5 allows to perform extraction operations from the sources, transformation and insertion of data in the *Data Warehouse*. An OLAP process, for carrying out queries, analysis tools and other applications that manage the data collection and delivery process in a useful and relevant way for users, in order to query data through applications. It allows understanding the different business needs from the collected data, leading to a decision process based on facts [9]. ETL is the most critical process in *Data Warehouse* design and consists of three steps:

- Extraction: Extracting data from various sources such as Excel, a *flat file* or others. This is followed by the transfer to the *Staging Area*, in which the ETL operates independently from the data sources.
- Transformation: Process of information treatment and data cleaning, to standardize them in size, type, correction of characters and data inconsistency.
- Load: Process of loading data to the *Data Warehouse*. This process allows organizations to choose to replace the data or add missing data in the time gap to be defined, depending on the business needs.

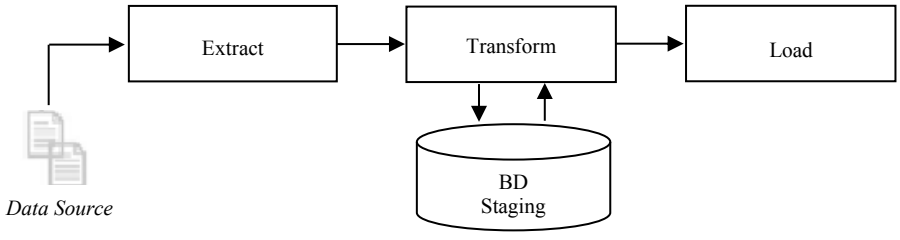

Fig. 5. ETL process

3. Literature Review

This work aims to characterize a BI system that allows an organization's managers to formulate strategies and assertive decision-making. In this sense, an innovative methodology is presented that defines ideas, methods, technical capabilities and artefacts through which the analysis, design, implementation and use of information systems can be carried out efficiently and effectively.

The methodology adopted in the work is the *Design Science Research* (DSR) for problem solving. According to Hevner & Chatterjee [12], this methodology allows the production of innovative artefacts and responds to organizational problems. After its construction, the evaluation takes place. The aim is to provide new knowledge within the reach of scientific evidence [28]. The fundamental pieces to understand the problem are the projected artifacts. Through its construction and application, it is possible to know and understand the difficulty of the problem and define a solution.

The methodology presented to be successful, it is essential to analyze your procedure from the identification of the problem to the result, that is, until the work is completed.

In figure 6 the application of the DSR to this research work is outlined, in which the five phases of the cycle of the proposed process are followed.

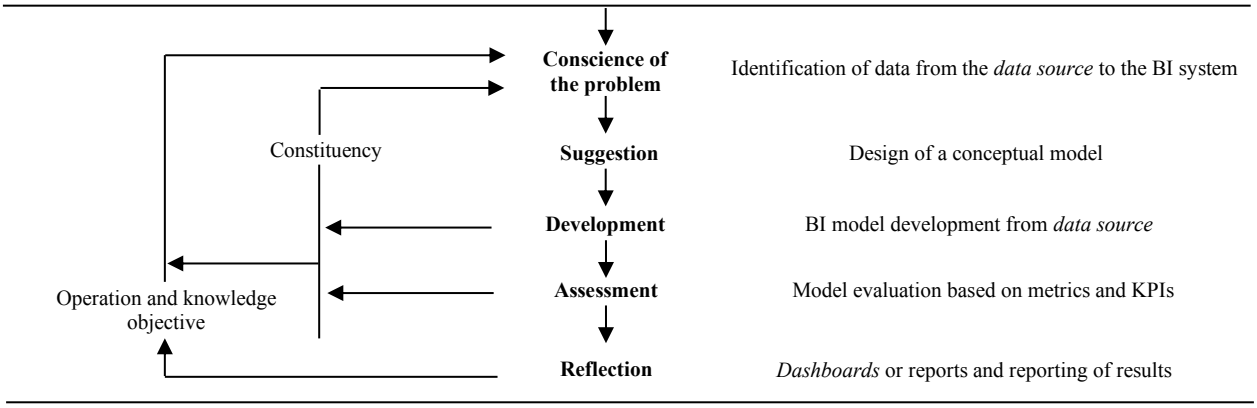

Fig. 6. *Design science research* model applied to this work

The first step is to identify the problem and the motivation. An organization must have standardized data for better accessibility and add value in the analysis of business indicators.

After identifying the problem, the objectives and goals to be achieved are defined. In other words, it creates a scalable BI solution for managing the organization. A conceptual model must be created to put into practice the proof of concept. Subsequently, the results obtained are analyzed.

After the first steps, the BI system design and development process is carried out in line with the DSR methodology, with the creation of the artifact, after collecting data from *Data Sources*. Within the gap of the BI system, the extraction, transformation and loading of data follows, for data analysis, the creation of metrics and KPIs for the business. Thereafter, *dashboards* or reports are created to present the results of the work.

4. Business Intelligence Conceptual Model

In this section we present the conceptual model of BI that synthesizes the information researched in the literature review, designing the model's architecture from the *data source*, data cleaning and formatting, KPI's relevant to the analysis and visualization rules in the creation of visual reports.

Development tools

The table 1 shows the tools that serve as examples to be used in the development of the model, which are grouped by context of experimentation and extraction, and data exploration.

Table 1. Development tools [21][22].

Development tools	Data management tools
MS SQL *Server Management Studio - Database Engine*	MS Excel
MS SQL *Server Management Studio – Analysis Services*	MS Excel & Power Query
Visual Studio - Integration Services Project	Power BI
Visual Studio - Multidimensional project and Data Mining services	

Initially, data is collected – *Data Source*, with the definition of the *Dataset* or *dataset*, from the data source - *Dataset* in formats such as, for example, CSV, JSON, TXT, XML or others, organized in the environment MS Excel & Power Query, for designing the *Data Warehouse* architecture in MS SQL *Server Management Studio*. Then, the ETL process is developed through *Visual Studio – Integration Services Project*. With the ETL process, we have data integration in the *Data Warehouse* and a favorable environment for the creation of the analysis model is created, through *Visual Studio – Analysis Services Multidimensional* and *Data Mining* Project, report generator, OLAP cube, *Data Mining*, among others. Finally, the use of Power BI provides visual analysis through the intuitive creation of *dashboards* or reports, with a *drag-and-drop* functionality interface to obtain the desired content, represented in a fluid way.

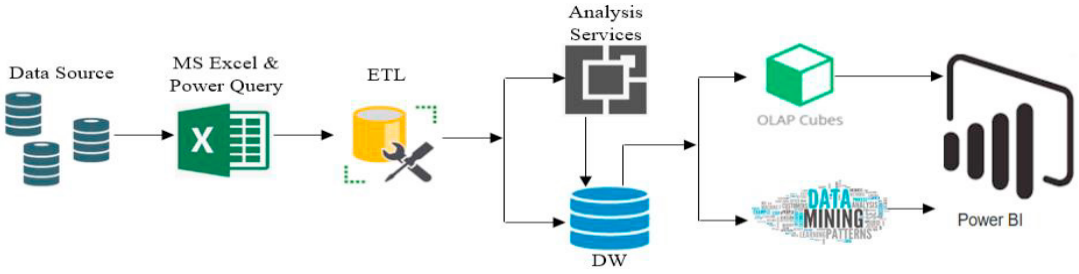

Fig. 7. Technological Architecture

Through the integration of several technologies and tools, to provide data from the *Data Warehouse*, it is possible to access the necessary data to test the data extraction and exploration tools. In figure 7, an integrated and global view of the environment is presented to support the *Data Warehouse*, the OLAP cube, *Data Mining*, views and data presentation.

Workplace environment

This topic addresses the technologies, tools and languages used, describing what they are, what they are for and how they fit into each phase of the model, according to the structure shown in figure 7.

1. Analysis of data and requirements through a proof of concept from *Dataset*.
2. *Data Warehouse* Modelling, Design and Implementation of ETL processes (Dimensions and Facts).
3. *Analysis Services Multidimensional* and *Data Mining* Project (OLAP Cube and *Data Mining*).
4. Visualization Layer: Construction of *Dashboards* or Reports in Microsoft Power BI for *data sources*.

Applications, infrastructures, tools and technologies are briefly described below and bring strategic benefits to organizations, enabling them to support business decisions and forecasts.

The technologies used to design the data knowledge extraction model for BI: SQL *Server Integration Services* (SSIS) and SQL *Server Analysis Services* (SSAS) from Microsoft SQL Server and Microsoft Power BI. As tools, Power BI, Microsoft Excel and Power Query (for the construction of data mapping tables) are used. As languages, we present: SQL Server language for the construction of tables, *views*, *stored procedures* and jobs from *data sources*, and *Visual Studio* for the construction of ETL, OLAP cube and *Data Mining*.

Microsoft Excel and Power Query allow the analysis, requirements gathering and implementation of data models that support the study of the main business indicators. The SQL Server *Management Studio* (SSMS) is an integrated

environment (client tool) that allows access, configuration, management and administration of the several components of SQL Server, enabling, the latter, the storage of large amounts of data from various sources [9].

In turn, SSMS provides tools to configure, monitor and administer SQL Server instances. The use of SSMS includes: implementing, monitoring and updating the data layer components used by applications, as well as creating queries and scripts. This tool is responsible for storing the data and procedures necessary to feed the decision support reports. In SQL Server, the design of databases, *tables*, *views*, *stored procedures* and jobs from operational data sources is carried out, channelling them to the respective multidimensional data models, later loaded into a *Data Warehouse*.

SQL Server also has data extraction tools (ETL), reporting tools (SQL *Server Reporting Services* – SSRS), analysis tools (SQL Server *Analysis Services* – SSAS) and features that allow you to create analytical applications. complete BI platform. Microsoft *Integration Services* are used to solve complex business problems by copying or downloading files, sending email messages in response to events, updating data stores, cleaning up data, and managing SQL Server objects and data. Packages can be used individually or together with other *packages* to meet complex business needs. *Integration Services* can extract and transform data from a wide variety of sources, such as CSV, XML, and relational *data sources*, and then load the data into one or more destinations. It also includes a set of tasks, integrated transformations and tools for building, executing and managing *packages*. *Integration Services* graphical tools can be used to create solutions or even program the extensive *Integration Services* object model to create *packages* and code custom tasks. This tool is responsible for implementing the ETL processes.

SQL *Server Analysis Services* (SSAS) analysis tools allow the creation of OLAP and *Data Mining* analytical applications for BI platforms. OLAP tools allow you to perform several actions on data cubes and fit into simple models for analysing and identifying patterns in data, such as *Data Mining*. The organization of data, imposed by *multidimensional schemes*, allows them to be analysed from different perspectives. However, analyzes that use this type of systems are based on hierarchies of concepts to consolidate data and to create views along the dimensions of a *Data Warehouse* [24]. In addition to these features, the OLAP tools normally allow you to visualize illustrative graphics of the data represented in the cube dimensions and to visualize a set of data organized in *multidimensional cubes*. Its purpose is to gather *datasets* in an organized and hierarchical way, providing a better organization of the data and helping a better understanding by the users [27].

Power BI is a tool for data visualization, as it allows the construction of dynamic tables and graphs and filtering of large volumes of data, which quickly help in decision making. This platform has a graphical and interactive interface, making it easier for users to explore the data through operations such as *drill* and try different types of presentations such as maps, graphs or animations, through interactive and detailed reports based on data prepared in SQL Server, OLAP cube or *Data Mining*, allowing end users greater flexibility in analysis, greater autonomy in accessing information from various *data sources*, greater ease in exploring large amounts of data, observing them in different ways and finding answers [29].

5. Discussion and Conclusion

After characterizing the various phases of the work, some conclusions and results can be considered. The first coincides with the importance of knowledge of data for organizations. Data stored in different sources must be extracted and explored for a platform such as *Data Warehouses* and associated with BI systems, to suit users and the organization, to improve the quality of information, and obtain the knowledge necessary for decision making.

In this sense, the importance of reviewing the literature must be recognized, allowing the study and characterization of platforms, applications and systems, for the process of extracting and exploring data knowledge for BI.

The research methodology phase contextualizes the development structure of the aligned work, with the objective to be achieved, through the creation of the artifact, from the extraction and exploration of relevant data that serve the BI system. The DSR methodology allows finding an acceptable solution to the problem. After analysing the problem and in accordance with this methodology, the solution found was the creation of a cataloguing typology, which makes it possible to identify how and which data extraction and exploration tools are best suited to the users' requirements.

The conceptual model presents a new definition for data extraction and exploration activities; the development tools to be used in an interactivity and multidimensional environment, allowing the extraction of knowledge from data for BI, so that in the future, it is allowed to improve the decision process, users and organizations that use the knowledge

extraction tools from data, connected with the BI system, insofar as its requirements are foundations in the adoption of technologies/tools, as they are based on *ad-hoc* situations, to analyse, explore and decide based on the data.

References

[1] Andre, L. (2020). What Is the Purpose of Business Intelligence in a Business? Finances Online - Reviews for Business: https://financesonline.com/purpose-business-intelligence-business.

[2] Aruldoss, M., Lakshmi Travis, M., & Prasanna Venkatesan, V. (2014). A survey on recent research in business intelligence. Journal of Enterprise Information Management, 27(6), 831-866. https://doi.org/10.1108/JEIM-06-2013-0029.

[3] Bonel, C. (2015). Afinal, O Que é Business Intelligence? Rio de Janeiro: 1ª Edição. Clube de Autores.

[4] Caldeira, C. (2012). Data Warehousing - Conceitos e Modelos. Lisboa: Edições Sílabo, Lda.

[5] Chaudhuri, S., Dayal, U., & Narasayya, V. (2011). An overview of business intelligence technology. Communications of the ACM, 54(8), 88. https://doi.org/10.1145/1978542.1978562.

[6] Chen, H., Chiang, R. H. L., & Storey, V. C. (2012). Business Intelligence and Analytics: From Big Data to Big Impact. Management Information Systems Quarterly, 36(4): 1165-1188.

[7] Dalfovo, O., & Tamborlim, N. (2017). Business Intilligence. Estudos e casos: na Gestão de Tecnologia da Informação como Inteligência nos Negócios. 1ª edição. Blumenau: Edição Clube de Autores.

[8] El-Sappagh, S. H. A., Hendawi, A. M. A., & El Bastawissy, A. H. (2011). A proposed model for data warehouse ETL processes. Journal of King Saud University - Computer and Information Sciences, 23(2), 91–104. https://doi.org/10.1016/j.jksuci.2011.05.005.

[9] Geetha, S., Dhanani, K. R., Doshi, P. P. (2020). Data Analysis and ETL Tools in Business Intelligence. V. VII, 127-131. DOI: https:/ / doi.org/ 10.26562/ irjcs.2020.v0705.007.

[10] Golfarelli, M., & Rizzi, S. (2009). Data Warehouse Design, Modern Principles and Methodologies. Data Warehouse.

[11] Grossmann, W., & Rinderle-Ma, S. (2015). Fundamentals of Business Intelligence. Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-46531-8.

[12] Hevner, A., & Chatterjee, S. (2010). Design Science Research in Information Systems. Design Research in Information Systems. https://doi.org/10.1007/978-1-4419-5653-8.

[13] Kimball, R., & Ross, M. (2013). The data warehouse toolkit: The definitive guide to dimensional modelling. John Wiley & Sons.

[14] Macaulay, T. (2016). A timeline of Business Intelligence: How decision-makers have been making sense of data. Retrieved January 29, 2018, from http://www.cio.co.uk/it-applications/business-intelligence-timeline-3429740/.

[15] Negash, S. (2004). Business Intelligence. Communications of the Association for Information Systems, Vol. 13 (February), 177-195. https://doi.org/10.1002/9781118915240.ch7.

[16] Nogués, A., & Valladares, J. (2017). Business Intelligence Tools for Small Companies. Barcelona: Apress.

[17] Nussbaumer, H., Revels, M. (2013). Data Mining and Data Warehousing in the Airline Industry. Academy of Business Research Journal; 2013, Vol. 3, p69.

[18] Santos, M. Y., & Ramos, I. (2009). Business Intelligence - Tecnologias da Informação na Gestão de Conhecimento (2 ed.). Lisboa, Portugal: FCA.

[19] Schutz, T. (2018). The 2018 Global Data Management Benchmark Report. [S.l.]: Boston, Massachusetts.

[20] Sherman, R. (2015). Business Intelligence Guidebook. Business Intelligence Guidebook. https://doi.org/10.1016/B978-0-12-411461-6.00002-2.

[21] SQL Server Management Studio (SSMS). (2017). Microsoft Docs. Disponível em: https://docs.microsoft.com/en-us/sql/ssms/sql-server-management-studio-ssms?view=sql-server-2017.

[22] SQL Server Integration Services. (2017). Microsoft Docs. Disponível em: https://docs.microsoft.com/en-us/sql/integration-services/sql-server-integration-services?view=sql-server-2017.

[23] Turban, E., Sharda, R., Delen, D., King, D., & Aronson, J. E. (2017). Business Intelligence: A Managerial Approach (2nd ed.). Prentice Hall. Retrieved from https://books.google.com/books?id=IvZ0RAAACAAJ&pgis=1.

[24] Vercellis, C. (2009). Business Intelligence: Data Mining and Optimization for Decision Making. Politecnico di Milano, Italy: A John Wiley and Sons, Ltd., Publication.

[25] Zea, O. M., Castro, J., Paredes-Gualtor, J., & Mora, S. L. (2019). A Hybrid Infrastructure of Enterprise Architecture and Business Intelligence & Analytics for Knowledge Management in Education. IEEE Access 7 (2019), 38778ś38788. https://doi.org/10.1109/ACCESS.2019.2906343.

[26] Zentut. (2021). Kimball vs Inmon na arquitetura de data warehouse. https://www.zentut.com/data-warehouse/ralph-kimball-data-warehouse-architecture/.

[27] N. Mateus-Coelho, M. Cruz-Cunha, and L. G. Ferreira, “Security in Microservices Architectures,” Procedia Comput. Sci., vol. 181, pp. 1225–1236, Jan. 2021, doi: 10.1016/J.PROCS.2021.01.320.

[28] M. M. Cruz-Cunha and N. R. Mateus-Coelho. (2021). Eds., Handbook of Research on Cyber Crime and Information Privacy. IGI Global

[29] Mateus-Coelho, N., Cruz-Cunha, M., & Silva-Ávila, P. (2021). Application of the industry 4.0 technologies to Mobile Learning and Health Education Apps. FME Transactions, 49(4), 876–885. https://doi.org/10.5937/fme2104876m