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Review Article

Review of Business Intelligence Implementation in Healthcare

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Abstract *- Business Intelligence (BI) is an emerging interdisciplinary research area that is adopted in numerous business sectors. It involves extracting information from huge amounts of data and presenting it to stakeholders in an accurate decision context. There are many BI implementations in the healthcare sector that aim at analyzing data, supporting decision-making predictions, and achieving overall improvements in the diverse facets of the sector.*

This research, in its first phase, surveys the most relevant studies carried out in this domain to date. While in the second phase, content analysis techniques were utilized to identify the various objectives of BI adoption in healthcare, stakeholders, success factors, and adoptions outcomes. The study then classifies the literature based on the BI technologies implemented, beneficial stakeholders, and the type of healthcare improvement targeted. Analytical research and the Information Systems (IS) success model facilitated the recognition and review of the most effective factors of BI improvements in healthcare. Finally, the lessons learned and some of the most promising future lines of research are discussed.

Keywords *- Business Intelligence, Healthcare, Data Warehouse, Data analysis, Decision-making, Information systems success model.*

I. INTRODUCTION

The rapid growth of technology use in the business environment has generated huge amounts of digital data resulting from the volume of transactions. Technological advances have made the use of Information Technology (IT) tools and techniques a necessity for streamlining operations in all businesses and industries [1]. Not only for business operation and development but also for supporting decision-making based on real information through the adoption of BI technologies. Every organization intends to become an intelligent organization and gain a competitive advantage in their market by implementing new technologies and innovative BI solutions, especially in the healthcare sector [2], [3].

The healthcare sector involves a variety of numerous stakeholders, including physicians, medical staff, insurance companies, government, regulating agencies, service providers, medical suppliers, and users who need the provision of reliable and secure services [4]. Dealing with and maintaining all these interconnected relations between all these stakeholders is very difficult without the use of technology. Furthermore, these relations are more sensitive than in other industries and businesses as they involve human life and wellness. For these reasons, it is essential to implement IT in healthcare to gain the benefit of using technology toward facilitating processes and improving services [5].

From the previous discussion, the healthcare sector has enormous amounts of data, and there is an urgent need to gather and process this information to make accurate and timely decisions based on current data. One of the solutions to improve the decision-making process is BI tools is used to transform raw data into smart information and knowledge [6]. BI technologies capture the organization's strategy and apply their tools to help manage and refine business information to make more effective business decisions in various scopes [7]. They provide the healthcare sector with the capabilities of transferring volumes of data from various sources into a shared depot to enable analysis and drill down into assured aspects and creating prudence of operational process to provide a decision support mechanism.

The paper is organized into six sections beginning with this introduction. The following sections present BI technology and its many components and techniques that serve as background for this study. The next section outlines the research methodology utilized to review, categorize, and analyze relevant literature in the healthcare sector. The subsequent section presents a brief summary of the reviewed papers in a table format. Section four focuses on the classification and analysis of the literature based on the specified criteria. Finally, the last section provides a summary and addresses the future direction of the research.

II. BUSINESS INTELLIGENCE

To evaluate the benefit of adopting BI in healthcare, we must first define the BI and its core technologies and techniques. The expression BI was introduced by an IBM researcher in 1958, as he defined it as the “ability to understand the interrelatedness of current data in many sides as to lead decision in respect of a wanted purpose and gain the competitive advantage” [8]. In recent years, BI was described as “concepts, methods and tools to improve and

restructure the organization process and decision" [9]. BI was also defined by Zeng et al.as "the process of extraction, handling, and diffusion and analysis of information that has an objective, the reduction of uncertainty when making strategic decisions" [10].

BI, by its definition, consists of three main stages: data storage integration, analysis, and information presentation stages [6]. Currently, many BI components are used to support decision-making as a part of integrated systems and suites or as distinct technologies.

The core BI components are [5], [11]:

- DW: Data Warehousing provides storage space for thematic stowage of integrated, aggregated and analyzed data.
- ETL: Extract-Transform-Load tools that are responsible for data transfer from operational or transaction systems to DWs.
- OLAP: On-Line Analytical Processing tools that allow users access and which analyze and model business problems and share information that is stored in DW.
- DM: Data Mining tools for determining patterns, generalizations, regularities, and rules in data resources.
- Reporting: Ad-hoc inquiry and reporting tools: for creating and utilizing different synthetic reports; and presentation layers that include customized graphical and multimedia interfaces to provide users with information in a comfortable and accessible form.

BI tools help users understand complex processes and relationships through easily assimilated, customized visual reports that help in making timely and informed decisions, taking actions that will improve performance, and understanding how their actions affect the entire organization [12]. Many business sectors usually utilize BI dashboard tools in the presentation phase to deliver information for stakeholders and end-users [6].

BI tools are used presented to help the healthcare sector in making precise diagnoses and treatment, both in short and long-term care. In many cases, they are used to estimate alternative treatments based on data analysis. In addition, they are also utilized from the administrative healthcare institute's perspective to assess and report on the cost and benefit of many operations in departments and units.

III. METHODOLOGY

This section describes the methodology used to review, categorize, and analyze relevant research papers focusing on the implementation of BI in the healthcare domain. This is carried out in two phases, with the first concentrating on reviewing the literature and identifying each paper's research objective and results. The output of this phase is presented in the next section, *BI Adoption in Healthcare*, while the second phase is covered in the *Review and Analysis* section. Phase two involves a thorough investigation of BI technologies used, stakeholders, and the introduction of critical factors affecting the successful adoption of BI in healthcare. This is followed by classifications based on core stakeholders' perspectives and these success factors.

In order to select the most relevant literature, appropriate keywords that refer to the use or adoption of BI in the healthcare sector were used. A search of Google Scholar and the main sources of academic research papers was conducted including, the IEEE electronic library Xplore. The time span for sources examination was from 2011 to 2019, since BI and computing technologies are growing fast, and we are interested in the state-of-the-art. Based on the outlined search criteria, we studied many scholarly works addressing various implementations of BI in the healthcare domain. For this paper, we limit our review to twenty research papers.

The goal of this research is to analyze each paper, discover its stated objectives for adopting BI in the healthcare domain, the BI technologies used, how well they were able to meet those objectives, and the lessons learned.

Content analysis and analytical research procedures were used to identify the crucial factors affecting the successful adoption of BI in healthcare. These procedures aim to recognize, document and categorize factors. Subsequently, two lists of main factors emerge. (a) Medical factors, i.e., improving medical decisions like diagnosis, detecting, predicting, and testing, of diseases, etc. (b) Non-medical or administrative factors, e.g., assisting with managerial decisions like cost reduction of operation, consumables, and services, and improving services quality, human resource benefits, etc. This characterisation is then used to classify the reviewed literature, as well as all of the benefits of utilizing BI in healthcare based on core stakeholders' perspectives.

After laying out the methodological steps of the research approach, the next section presents a high-level classification of the reviewed scholarly articles. The purpose is to effectively present findings in preparation for the upcoming review and analysis.

IV. BI ADOPTION IN HEALTHCARE

The use of BI in healthcare, like any other technology-based approach, is to resolve business challenges and streamline operations. As discussed earlier, challenges in the healthcare sector are more complex and interrelated than other businesses and industries. Examples of these challenges include maintaining the privacy and confidentiality of patients clinical and administrative information, improving service quality, reducing cost, enhancing time management, and complying with laws and regulations [2], [13].

Obviously, BI applications have been under investigation and are being utilized internationally across many healthcare institutions[14]. Therefore, there is considered able research that analyzes and discusses adopting BI technologies in the healthcare sector based on various approaches. One such approach explores utilizing

the available open-source BI tools and their applicability in the clinical sphere taking into account the general characteristics of the healthcare sector environment [15], [16]. Another approach uses the well-known DeLone and McLean Information Systems (IS) success model to investigate the adoption of BI technologies in the sector [17], [18]. Correspondingly, research [19], [20] has shown that the success of BI implementation in the healthcare domain requires three-dimension factors. These are (1) organization factors, such as managerial support, commitment and sponsorship, (2) the process factors, including adoption plan, team composition, interactive development approach, and user interaction. And (3) technology factors, such as, framework scalability and flexibility, and sustainable data quality and integrity. Each of these three dimensions has many factors that are referred to as Critical Success Factors (CSFs), that are defined as "the limited number of areas in which results if they are satisfactory, ensure successful competitive performance for the institute", or "the few key areas where things must go right to achieves their goals" [21].

Table 1. Bi implementation in healthcare

Author	BI Implementation Focus
Ashrafi, Noushin Kelleher, Lori Kuilboer, Jean-Pierre 2014	Improve the healthcare delivery in the USA by using BI capabilities to support the healthcare institutes achieve their effectiveness to improve quality care and reduce cost how BI creates a combination of data to extract useful information to support decision making [2].
Olszak, Celina M Batko, Kornelia 2012	Discussed the current healthcare situation in Poland and how to achieve the full benefits of BI implementation based on historical data collected, to enhance decisions making process and to improve the patient outcomes, quality of medical services, and reduce costs, instead of the further improvement of medical necessity as the essence of BI in healthcare sectors [4].
Gaardboe, Rikke Nyvang, Tom Sandalgaard, Niels 2017	Empirically tested the DeLone-McLean IS success model on a BI system applied to 12 healthcare systems in Denmark. The success factors of BI implementation are system quality, information quality, use, user satisfaction, individual impact. The purpose of the study is to investigate which factors contribute to BI success [13].
Naderinejad, Marjan Tarokh, Mohammad Jafar Poorebrahimi, Alireza 2014	Explore whether BI implementation is affected by applying the Critical Success Factors (CSFs) model of BI (organizational, process, and technological) factors? To achieve intelligent healthcare institutes and their certainty is a high priority of service quality, taking into account the complexity of the relationship between these factors and the satisfaction of healthcare stakeholders in making accurate decisions [19].
Magdi, Dalia Ahmed 2019	Implementation of a DW to enhance operational and financial prospects. Factors include quality, cost-effectiveness, clinical, integration, and running costs reduction [22].
Obeidat, Muhammad North, Max Richardson, Ronny Rattanak, Vebol North, Sarah 2015	Investigate if emerging technologies and the implementation of BI systems have a positive effect in the healthcare domain. Focusing on these three main factors: service quality, cost reduction, and managing risks. The research showed that BI adoption was helpful in chronic disease management [23].
Khedr, Ayman Kholeif, Sherif Saad, Fifi 2017	Improve results in the healthcare sector obtained from healthcare institutes systems by conducting Framework results. Using BI to provide stockholders with accurate decisions based on enhancing the analytics information from integrating healthcare data using analytical tools [24].
Pereira, Ana Portela, Filipe Santos, Manuel Filipe Machado, José Abelha, António 2016	Use the implementation of BI systems to serve healthcare, and became more useful at Intensive Cares Unit(ICU) to make decisions, by creating availability of pervasive patient's and getting more positive aspect for patients' safety and care, improve the quality, reduce medical errors and, consequently [25].
George, Joseph Kumar, V Kumar, S 2015	Approve using of optimal DW structure for implementation of BI concepts on the healthcare sector to get accurate decisions to improve healthcare quality and also reduce the cost, improving patient care [26].

Davidson, MD Arthur, J 2015	Is the implementation of BI tools leveraging in the healthcare sector to achieve patient safety and healthcare institutes financial effectiveness and improve the healthcare sector by increasing efficiency and outcomes, reducing costs, this improving through the targeted BI application of health analytics [27].
Brooks, Patti El-Gayar, Omar Sarnikar, Surendra 2015	The readiness of healthcare institutes to develop its sector by conducting a BI framework used to create a domain-specific BI maturity model in the healthcare sector to achieve positive critical success factors for BI implementations is healthcare based on a conceptual structure readiness to improve either operational or financial and clinical [28].
Haque, Waqar, Bonnie Urquhart, Emery Berg and Ramandeep Dhanoa 2014	How BI techniques and tools can be applied to the healthcare environment using its system data to achieve this information more accessible and intelligible for healthcare stakeholders to make informed decisions based on BI implementation regarding resource allocation and enhancement of the quality of patient care [29].
Chen, Edward T 2014	Using BI tools to get accurate, informed decisions in the healthcare sector by extracting meaningful information from the data. Considered three technical issues to achieve the impact of the design, build, implementation, and support of the system [30].
Karami, Mahtab Fatehi, Mansoor Torabi, Mashallah Langarizadeh, Mostafa Rahimi, Azin Safdari, Reza 2013	The opportunity of BI adoption in the healthcare sector to achieve strategic goals and objectives, and impacts to improve the healthcare institute's performance from many affecting factors, such as operations, finance, quality, eliminate information asymmetry, specially in the radiology unit [31].
Muraina, Ishola Dada Ahmad, Azizah 2012	The capabilities of BI techniques to facilitate decision-making in a university hospital. Study to determine the diseases that require crucial attention among the students' patients, using DW for forecasting future activities to know the medical statistics [32].
Kolowitz, Brian J Shresth, RB 2011	The effectiveness of IT in the healthcare domain and its impact on the healthcare process. Using federated Picture Archiving Communication Systems (PACS) as a case study for implementation BI to enhance the availability of information, to informed decisions and improve healthcare sectors to get intelligence knowledge management and clinical workflow[33].
Ahmed, Soha El Seddawy, Ahmed Ibrahim Nasr, Mona 2019	How to detect and predict diseases through BI applications. DM techniques were used to help expedite the diagnosis and prediction of diseases. Diabetes was used as a case study to detect and predict the disease from the patient complications [35].

Table 1. represents a summary of the reviewed research papers with a short description that contains their scope, purpose, results, and contents of the work.

In the following section, additional literature classifications will follow that focus on the BI technologies utilized, stakeholders, and the targeted BI objectives and contributions to the healthcare sector.

V. REVIEW AND ANALYSIS

The objective of this review is to investigate which facets of healthcare could be improved by the adoption of BI tools and techniques and how. This is achieved through identifying and highlighting from the literature the BI components, how they were applied, and the results realized from such utilization.

For this purpose, and on a high-level review, the literature is categorized into two groups: namely, research that investigates the CSFs required for the successful adoption of BI in healthcare on the one hand. And literature that explores the goals and benefits of BI adoption in healthcare on the other. According to the literature [19], [28], [34], the CSFs include system quality, information quality, BI use, user satisfaction with the BI implementation, and what users are able to do with BI tools as individual impact. BI maturity model is measured by an organization, process, and technological factors to demonstrate the efficacy of the framework by applying it to the development of a BI in healthcare.

The second group of literature explores the benefits and goals intended for adopting BI in healthcare. It is obvious that the overarching goal is improving the

healthcare services as a whole, but each research focuses on its own perspective or area of improvement. A review is conducted of research goals depending on its intended objective, contributions, and outcome, as shown in Table I. All of the reviewed literature in this category targets improving either medical and/or administrative facets or aspects of healthcare. The medical aspects include how the adoption of BI in healthcare supports the medical staff in detecting and predicting diseases and, as such, improve decision-making. Another area is how the adoption of BI improves medical services by availing and integrating departmental medical information to stakeholders. Other facets include reducing medical errors, patients' safety, and the most desirable target patients' satisfaction. On the side of the administrative aspect, the focus is on managerial and financial factors, for example, reducing cost, increasing revenue, improving services quality, decision-making, integrating departmental administrative information, etc.

While all the reviewed literature targets healthcare improvement in the sector, most only focus on BI adoption at a single healthcare institute. Because BI, by its definition, enables data integration and aggregation for decision-support, we believe that sharing a regional or national DW better exploits BI strengths and achieves the utmost benefit from its adoption. This area of research, i.e., the aggregation and sharing of data across healthcare institutes in the sector, requires more research.

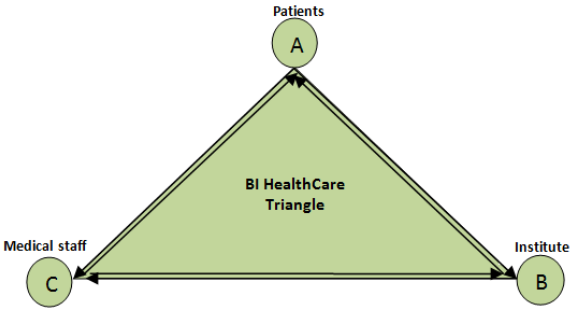

Fig. 1 BI Healthcare Core Stakeholders

From the literature review, we determine that all the healthcare beneficiaries are stakeholders of BI adoption in the sector, including governments, communities, healthcare institutes, healthcare staff, and the patients. The three main beneficiary groups or core stakeholders of BI adoption are patients, healthcare institutes, and medical staff since they directly interact with, influence and are influenced by BI application. On the other hand, there are many relationships between these main stakeholders, as illustrated in our healthcare service triangle in Fig.1. These bidirectional relationships include patients' need for service that is provided by medical staff who work for the institutes. The service providers, in return, aspire for financial returns and a good reputation from the patients.

The following is a summarization from the literature of the benefits of adopting BI for each of the three core stakeholders' groups.

A. Patients

Healthcare is an essential universal requirement of populations in all countries around the world. Patients and their satisfaction is the cornerstone of healthcare service, its enhancement, and the ultimate goal of BI implementation in the sector. The patients' satisfaction factors are covered by most of the reviewed papers, and all were improved by the BI implementation.

B. Medical Staff

They include physicians, nurses, medical assistants and technicians. Through all the reviewed literature, all the medical activities that are carried out by staff became more efficient with BI. Many clinical and diagnostic factors of the healthcare process were improved, including reducing medical errors and inaccurate diagnoses. Also, the process of predicting and detecting diseases and trends is greatly enhanced by mining through the wealth of available historical data. As a result, improvements were reported in the literature about service quality to patients, which is one of the main objectives of BI and technology adoption as a whole.

C. Healthcare Institutes:

Throughout the literature, there is consensus that healthcare institutes have realized many advantages through the implementation of BI. These include decreasing running costs and increasing revenue and information availability to their stakeholder. The availability of such timely historical information helped in improving administrative decisions related to institutes' management, and this was reflected in patients' services.

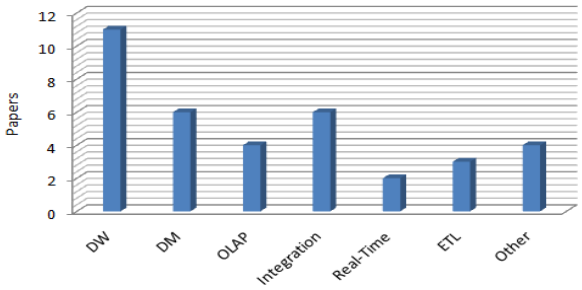

Fig. 2 BI Technologies

Switching to the issue of BI components utilized, the reviewed literature includes an investigation of the implementation of complete BI suites as well as separate components and technologies. Fig. 2 recognizes and classifies the BI technologies adopted in healthcare implementations in the reviewed literature. Clearly, every research paper reviewed could adopt more than one technology or technique, and the most technology used based on Fig. 2 is the DW. This is an expected finding, as the DW is the core BI component around which the whole BI framework is developed since it integrates and aggregates data. The second most frequently employed BI technologies are data integration and mining. The two are vital technologies for trend analysis, drill-down and prediction.

The following classification of the reviewed literature is based on their BI implementation objectives, CSFs, and their advantage to the three main stakeholder groups outlined earlier. Based on the previous discussion about the IS success model and the literature, we recognize the following six CSFs groups:

a) Detect and Predict Disease

Analyzing historical information is one of the main advantages of BI tools, especially in the healthcare domain, where huge data is available either in the local repository or the DW. BI technologies enable predicting and detecting diseases, not for specific patients' but for chronic disease trends or seasonal epidemiology. This serves patients by saving their lives and the healthcare sector by improving performance.

b) Improve Services:

Healthcare service improvement is the cornerstone of the healthcare enhancement process because it affects the quality of both operational and clinical services. The main objective of all healthcare stakeholders is the improvement of healthcare quality, either operational or clinical.

c) Enhance Decisions:

Improving the decision-making process is one of the main targets of BI in the healthcare sector. The BI tools and technologies make the information available to stakeholders. One of the key BI features is the drill-down through the DW to investigate trends and predict. This helps medical staff to quickly diagnose dieses and saves patients life.

d) Financial Performance:

Managing and controlling operations and other costs are the top motivators for healthcare institutes to implement BI. Minimizing cost and maximizing revenue is a primary target, especially if the institutes are of a profitable nature.

e) Patient Satisfaction:

This is a universal indicator of the quality of the healthcare sector. The literature groups all the following factors under the patients' satisfaction category: patients' safety, medical errors reduction, cost reduction, service quality, and favorability of services.

f) Data Integration:

In healthcare, patients' historical information is critical and timely, especially in intensive care or emergency units. The integration of data assists in providing information to make timely, accurate and informed decisions. This is a fertile area of research in the healthcare sector, i.e., the integration of medical and administrative information.

Table 2. Main implementation objectives

	BI Main Objective	Reference
1	Detect & Predict Disease	[23] , [32], [35]
2	Improve Services	[2], [4], [18] , [19], [22], [23], [25], [26], [27], [28], [29], [31], [33]
3	Enhance Decisions	[2], [4], [19], [24], [26], [29], [30], [33]
4	Financial Performance	[2], [22], [23], [26], [27], [28]
5	Patient Satisfaction	[2], [19], [22], [23], [25], [26], [27]
6	Data Integration	[2], [4], [19], [24], [26], [29], [30], [31], [33]

Table 2. summarizes the BI implementation objectives of the reviewed research based on the six core CSFs. As explained earlier, these CSFs were derived from research on the IS success model for BI in healthcare. It is reassuring that Table II shows that the most prevalent BI objective in the literature is "Improve Service". This is followed by "Data Integration" because the integration of information leads to improving the decision-making process and, eventually, the healthcare service as a whole.

The comprehensive literature review and analysis of objectives and the relationships between core stakeholders and the objectives have clearly demonstrated and highlighted the many advantages of BI adoption healthcare. The next section summarizes findings, limitations, lessons learned and provides direction for future work.

VI. CONCLUSION AND FUTURE WORK

This paper has reviewed the state-of-the-art with respect to BI in the healthcare sector and surveyed the most relevant work in this area to date.

In fact, we have classified the studied literature not only by the objective of BI implementation and the technologies used but also by the most effective factors leading to healthcare enhancement. Content analysis and the IS success model were used to recognize and analyze the most effective factors of BI improvements in healthcare. In addition to the literature analysis, the identification of the essential characteristic factors affecting the successful BI adoption in healthcare is among the main outcomes of this study.

The implementation of BI in the healthcare domain is an active research area with plenty of publications that relate to improving the efficiency of both medical and administrative characteristics. In fact, our analysis of the literature has shown that there are great benefits and advantages from its adoption. An interesting area that still requires more researchers' attention is investigating the influence of data integration regionally and nationally

across the healthcare sector. Bearing in mind the various privacy and security issues prevalent with all healthcare information.

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