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Review Article

Business Intelligence Implementation in Healthcare - A Case Study in Sudan

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Abstract - There are many universal challenges facing healthcare worldwide, including rising costs, the numerous stakeholders, their complex interrelationships, varying interests, and volumes of highly sensitive and regulated data. Business Intelligence (BI) technologies offer tools and techniques for streamlining operations and supporting decision-making based on real information. This research investigates the value and advantage of adopting BI technologies to enhance the healthcare sector. It proposes a BI framework that enables analyzing data, supporting decision-making, predictions, and achieving overall improvements in the sector's diverse facets. A mix of research methods was used to validate the framework, including content analysis to identify the main characteristics of healthcare services and factors affecting BI adoption's success, along with a case study implementation of the proposed BI solution. Data was collected from three major healthcare providers in Sudan. Key stakeholders' interviews served to identify the main features to examine based on their corresponding Hospital Management Systems (HMSs). The study focuses on three groups of identified factors, namely provider, service, and time management. Analysis of results from the implemented BI model supports the research hypothesis that utilizing BI yields reliable consolidated information, knowledge-based decisions, improved processes, and improved healthcare services.

Keywords - Business Intelligence, Healthcare, Data Warehouse, Data analysis, Decision-making.

I. INTRODUCTION

All business environments aim to optimize their decision-making processes by analyzing historical data on time while streamlining operations and controlling costs to gain a competitive advantage [1]. The rapidly growing use of Information and Communication Technologies (ICT) by industries and businesses to support their environments has generated huge amounts of data from various transactions [2].

The healthcare sector has complex processes and involves a variety of stakeholders with countless interrelationships and varying interests. These stakeholders include medical Staff, insurance companies, government, regulating agencies, service providers, medical suppliers, and above all patients, who need the provision of reliable and secure services [3]. Maintaining and managing all of these interconnected relations between these stakeholders is very difficult without using technology. Furthermore, these correlations are more critical in healthcare than in other industries and businesses as they involve human life and wellness [4]. For these reasons, it is essential to implement ICT in healthcare to gain the benefits of technology utilization toward facilitating processes, improving services, and the sharing of data [5].

Currently, technology and its applications are widely used in healthcare, even in developing countries like Sudan. Examples are HMSs, Hospital Information Systems (HIS), Electronic Medical Records (EMR), Enterprises Resource Planning (ERP), and specialized applications such as Radiology Information Systems (RIS), etc. These systems facilitate healthcare processes and services but at the same time, face many challenges. Some of which are technical including the rapid development of medical technologies, their mounting costs, and data integration and security [6]. Additionally, there are non-technical issues such as the rising expectations and entitlements of patients, and the affordability of services either from cost or quality care perspectives.

The widespread application of the aforementioned healthcare systems has necessitated the need to investigate and identify the main characteristics or factors influencing the successful implementation of these systems. These factors create pressure to (1) increase stakeholders' access to healthcare information, (2) grow the diversity of medical services, (3) change the approach to financing and managing of healthcare, and, (4) stress the growing importance of ICT in the healthcare sector [7]. Recent research [8], has shown that one of the best indicators of systems' effectiveness is stakeholders' satisfaction. On one hand, the patients' healthcare provider of choice is preferably close to their homes, provides quality care, with affordable cost, accurate diagnoses, with minimal medical errors, and minimum waiting time. All of these factors comprise what is referred to as **patients' satisfaction**. While on the other hand, healthcare service providers' objective is to reduce costs, increase revenue, while improving services' quality and achieving their most desirable target, i.e., patients' satisfaction. Providers aim at increasing patients' visits frequency while maintaining their satisfaction and that of the medical and administrative Staff by continuously improving the environment [9].

This research proposes a BI framework for healthcare that integrates data and information into a central repository to assist stakeholders' in decision-making and predictions. It also investigates the main characteristics influencing the BI model implementation in Sudan based on stakeholders' views and expectations. Finally, a case study including a BI model implementation for three healthcare providers was used to substantiate findings.

The paper is organized into six sections beginning with this introduction. The following section presents BI technologies' use in healthcare and it serves as a background for this study. The next section outlines the proposed BI framework. Section four describes the research methodology utilized, including the content analysis process, exploratory interviews, data collection criteria, categorization of the explored features, and the BI tool utilized for the case study. The subsequent section focuses on the analysis and discussion of the results of the study. Finally, the last section provides a summary and addresses the future direction of the research.

II. BI IN HEALTHCARE

BI tools and technologies facilitate access to data and information, enable the support of decision-making processes and real-time reporting to serve stakeholders [10]. They simplify analyzing the volumes of operational and clinical data, enable businesses to assess their competitiveness, achieve customer satisfaction, and also to keep good relations with suppliers [11].

The application 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. For example, the medical aspects focus on how the adoption of BI supports the detection and prediction of diseases [12]. Similarly, there is plenty of scholarly work on how it improves medical services by availing and integrating medical departmental information, reducing medical errors, improving patients' safety, and achieving patients' satisfaction [13]. The administrative aspects focus is on managerial and financial factors, such as improving services quality, integrating departmental information, and supporting decision-making [14].

BI by its definition is comprised of three main stages, namely, data storage integration, analysis, and the information presentation stage [15]. Currently, many BI components are used to support decision-making in healthcare, as a part of integrated systems and suites, or as distinct technologies [16i]. The tools and technologies used can be summarized as Data Warehouses (DW), Data Mining (DM), Online Analytical Process (OLAP), Extract Transform and Load (ETL) to extract information, these tools provide fundamental support for decision-making in the healthcare domain.

Despite the widespread utilization of technology and HMSs throughout healthcare, there is a severe lack of sharing and integration of information between the many stakeholders. As recent research [17], [18] has shown, the integration and aggregation aspects of BI offer the ability to transfer volumes of data from various sources into a common depot to enable analysis and drill-downs into certain aspects. This facilitates creating prudence of operational processes to provide decision-support and prediction mechanisms and to empower stakeholders.

This study focuses on the deployment of BI capabilities in the Sudanese healthcare sector by studying the current situation and determining the challenges while contributing to a BI framework. The research hypothesizes that adopting BI technologies in healthcare leads to improvements in the sector.

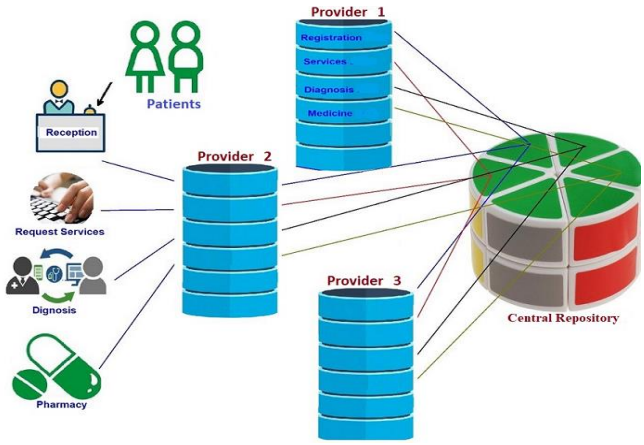

Fig.1 Patients' information lifecycle

Fig. 1 illustrates the exiting patients' information flow. It shows the registration, services, diagnosis, and therapeutic information stored in each local provider's databases. As will be explained in the next section, the proposed framework integrates select information extracted from these local databases into a common repository.

III. PROPOSED FRAMEWORK

The proposed BI framework integrates carefully chosen data from healthcare providers into a central repository to be used by the appropriate stakeholders. The data is selected while maintaining the confidentiality, integrity, and security of the information.

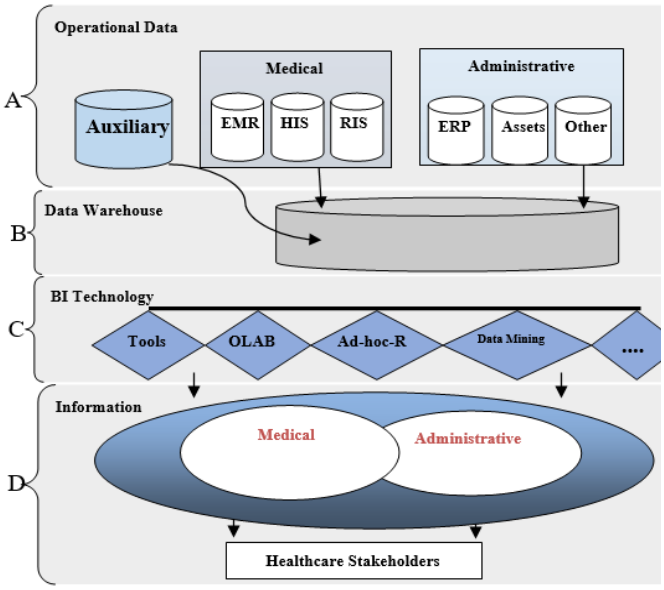

Fig. 2 BI framework for healthcare

The framework is composed of four layers, as shown in Fig. 2, and they are described as follows:

A. Operational Data

This layer is composed of transaction data supplied by healthcare providers through their electronic systems as shown in Fig.2. This includes unidentifiable patients' medical and services related data as well as providers' administrative data about services availability, cost, human resources, departmental data, etc. The administrative data is included since it has an indirect influence on the operations of the provider. The layer also integrates auxiliary data from the Ministry Of Health (MOH), regulating agencies, an international organization such as the World Health Organization (WHO), etc. This layer is the cornerstone of the framework model as it contains vital data from all participating stakeholders that are essential in building the DW.

B. Data Warehouse

The inbound data from the previous layer is aggregated and stored here in the central repository. The BI processes of ETL are performed during the restructuring and migration of the data in the first layer. Access to this digital repository is granted to all participating stakeholders based on their security level and privilege. The objective is to provide them with reliable decision-support information by utilizing BI tools while maintaining the privacy of patients' personal information and the confidentiality of participating institutes.

C. BI Technologies

This layer contains many BI tools that help stakeholders in understanding the complex processes and data correlations. These include easily customizable visual reporting and querying tools to make timely and informed decisions. For example, OLAP, data mining, Ad-hoc, etc.

D. Information

This layer contributes to the creation of the appropriate stakeholders' information dashboards, Key Performance Indicators (KPI), and reports.

In this layer, useful information and insight are presented to stakeholders in an easy-to-understand visual manner. Similar to the data layer, the information presented here is grouped based on its type, i.e., medical and administrative.

From the analysis of healthcare processes, and the exploratory interviews, the main stakeholders of the BI framework in Sudan are categorized into the following seven groups:

a) Government and Regulators: This is primarily the MOH and the regional health authorities that manage and control the health sector in Sudan together with regulating agencies. MOH creates national healthcare policies and procedures and monitors prevalent diseases and public health epidemics. Regulating bodies have oversight powers over the operation of public and private providers, including hospitals, clinics, labs, etc. They monitor all aspects of healthcare providers' services.

b) Supporting Organizations: Such as international organizations like the WHO, and other local and charitable organizations that contribute to medicines, equipment, materials, and in-kind donations. They provide technical assistance to the MOH and exchange statistical, demographic, and world standards information. They are involved in monitoring epidemics and public health issues.

c) Medical Suppliers: They supply healthcare providers with medical consumables, pharmaceuticals, therapeutics, medical equipment, etc. MOH and its monitoring bodies regulate these suppliers and exchange specifications, demand data, etc., with them and with the healthcare providers. This data is used by all these stakeholders to plan and make better demand predictions.

d) Insurance Companies: Health insurance companies utilize the medical services available and cost information of suppliers to negotiate better contracts with them. This is an important factor in reducing the cost of treatment while maintaining quality. They also explore the most common diseases, patients' satisfaction, and coordinate with MOH and regulators to improve services.

e) Patients: They are the central stakeholder that the whole healthcare system revolves around. Patients demand quality service at a reasonable price. The proposed framework helps patients by making the information available.

f) Medical Staff: These are the physicians, medical and administrative staff at the healthcare providers' facilities. They already use electronic systems that deal with patients' medical records and demographic data. The framework

provides them the ability to make a better and more accurate diagnosis.

g) Healthcare Providers: As indicated earlier, most of these providers use electronic systems to manage their operations and facilities. The framework gives them the technologies and tools to integrates their separate data, and to make timely and informed decisions.

This research intends to validate that the proposed framework provides many benefits to stakeholders. For example, providers and regulators will be empowered to evaluate and monitor different performance aspects of the services delivered against regional and national providers and international standards. While patients and administrators will be enabled to assess services' availability, cost, average waiting times, quality, etc.

To gain a greater understanding of the components of the proposed BI model and the factors affecting its successful adoption, the next section explores the creation of a basic BI implementation model founded on the abovementioned framework. It also identifies and examines the effect of a comprehensive set of variables on its adoption based on the empirical case study in Sudan.

IV. METHODOLOGY

This section describes the methodology used to realize the research objectives. Initially, a basic BI implementation model was developed based on the proposed framework. Then the discovery of the main factors involved in its successful adoption in the Sudanese healthcare sector was conducted. Content analysis was utilized for this investigation together with an exploration of key stakeholders' assessment of the identified factors. Finally, an implementation case study is utilized to investigate the value and effectiveness of the proposed BI framework.

A. BI Technology

Microsoft SQL Server BI tools were used for the case study implementation [19]. These tools support BI services concepts by utilizing SQL Server Analysis Services (SSAS) as technology from the Microsoft BI stack to develop (OLAP) solutions, and SQL Server Reporting Services (SSRS) to create reports from multiple data sources with wealthy data visualization either charts or maps.

B. Study's Target Group

Three large private hospitals in Khartoum, namely: (X) Sharg Alneel, (Y) AMC, and (Z) Aliaa hospitals, were designated as the target group for the study. These three healthcare providers were selected for many reasons including the fact that they are large hospitals with many departments and deliver a wide range of medical services. Moreover, they have decent ICT infrastructure and are already relying on HMSs for their operations. This means that historical data and logs are readily available electronically for the DW implementation. Correspondingly, the cooperation capacity of the hospitals' technology departments for scientific research played a role in their selection.

C. Data Migration

Each member of the target group utilizes their HMS in a different capacity and with a different approach. Strict data security, privacy, and integrity procedures were applied when designing the ETL strategy. Data was collected for three years, between June-2015 to May-2018. First, the medical data, and this includes a listing of all the clinical and diagnostic services provided and their cost. Together with patients' care and demographic data, such as treatment data per date\time, department, and cost. The second category is administrative data, including financial data, such as departmental revenue and expenses, hospital revenue and expenses, etc. Also included in the administrative data is human resource data, such as the number of Staff per department, departments' turnover, as well as logistics data.

The DW data model was designed, developed, and implemented using the Microsoft SQL Server. The data collected for the BI implementation was manipulated using the developed ETL strategy and then migrated and inserted into the DW.

D. Case Study Design

Content analysis methods resulted in the identification of many factors influencing BI implementations in healthcare. Exploratory interviews with hospital administrators and patients at the target group helped in highlighting and prioritizing these identified factors. KPIs, possible queries, and information dashboards were created based on the stakeholders' feedback to study the possible correlation between these factors, their significance and thus validate the framework.

To facilitate the impending analysis, these recognized factors are grouped into the following three interrelated categories:

a) Provider Management: This group includes many factors prioritized by hospital administrators in their quest for the delivery of outstanding quality services. They are divided into two subgroups, namely, patients' and staff satisfaction and financial factors. As previously explained, patients' satisfaction is the target of healthcare service providers. While human resource management reflects directly on the services they deliver, reducing operational cost and increasing income. It also indirectly affects patients' satisfaction and increases patients' visits frequency. Major factors in this subgroup are staff turnover, staff training, and motivation.

For the second subgroup, i.e., financial factors, healthcare providers strive to strike a delicate balance between increasing their revenue and reducing cost on one hand and improving the quality and availability of their services on the other. Consequently, providers monitor hospital units' revenue separately and collectively. An example of this balancing act is that sometimes providers opt to operate a low return service or department for the sake of patients' connivance. Since the integration of medical services at the same location leads to patients'

satisfaction. The BI model enables capturing this information through the appropriate KPIs and presenting it in the information dashboard.

b) Service Management: This group of factors is composed of medical service availability and service cost. As explained in the previous group of provider management factors, the availability of all clinical diagnostics, tests, and treatment under one roof is vital for patients' satisfaction. Availability and cost are essential factors from the perspective of many stakeholders including patients, regulators, insurance companies, and hospital administrators. For example, health insurance companies use this information to negotiate better contracts with providers, MOH uses it to plan its regional and national service coverage maps, patients use it to choose between providers, etc.

These vital factors play a major role in reducing the cost of treatment while maintaining quality. The BI model through the appropriate dashboards enables stakeholders to explore different aspects of services availability and affordability and draw their conclusions.

c) Time Management: Managing time is critical for healthcare providers as well as for patients. There is an inverse relationship between patients' frequency and services' availability. Without time management, this correlation leads to extended waiting and service times, and has a negative impact on patients' satisfaction and ultimately providers' revenue. To mitigate this situation, providers plan for each service station as an independent unit and provide adequate staff training. They also extend ample logistics services support, either implicit as hospital environment or explicit such as attention, care, and attitude toward patients. The BI model through the appropriate dashboard enables managing and monitoring all these factors.

After describing the research approach methodology, the next section presents and discusses the case study results from each of the outlined three groups of factors.

V. RESULTS AND ANALYSIS

The model was implemented to explore the benefits achieved by stakeholders from adopting BI technologies. Information dashboards were created reflecting the target group's (providers X, Y, and Z) administrators' and patients' perspectives. Results belonging to each of the three influencing factors groups outlined in the previous section are discussed in detail, and their impact on the study objective is highlighted.

Results are based on the BI implementation of the information dashboards created for this purpose. The target group administrators' goal is to optimize resources and assess their services' and pricing competitiveness. The factors examined in the case study are medical services' availability, patients' frequency, staff turnover, revenue, expenses, among others.

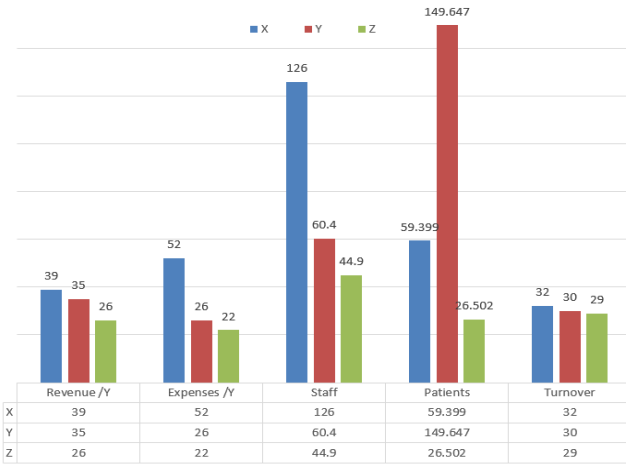

Fig.3 Administrators' dashboard 2015-2018

Fig.3 illustrates the provider administrators' dashboard investigating the correlations between the critical factors shown, i.e., providers' financial position, Patients' frequency, Staff, and Turnover. The units in Fig. 3 are as follows: Revenue and Expenses are in thousands of Sudanese Pounds (SDG), while Patients frequency is in thousands, and Staff in hundreds, and finally Turnover is a percent of the total Staff for the study period.

The dashboard in Fig. 3, is one of many available to hospital administrators and their shareholders that are created based on KPIs they have identified. The revenue, number of Staff, and the frequency of patients reflect the level of operation of the hospital and affect patient satisfaction. Turnover is directly impacted by staff satisfaction with their jobs and level of affiliation to their employer. As discussed in the provider management group of factors in the previous section, patients' and staff satisfaction has a direct bearing on the revenue.

It is clear from Fig.3 that provider Z has the highest Turnover during the study period since 32% of their Staff have left the organization. This may indicate that Staff is poorly selected, trained, or are complacent, and maybe underpaid and that further detailed analysis of this factor is required.

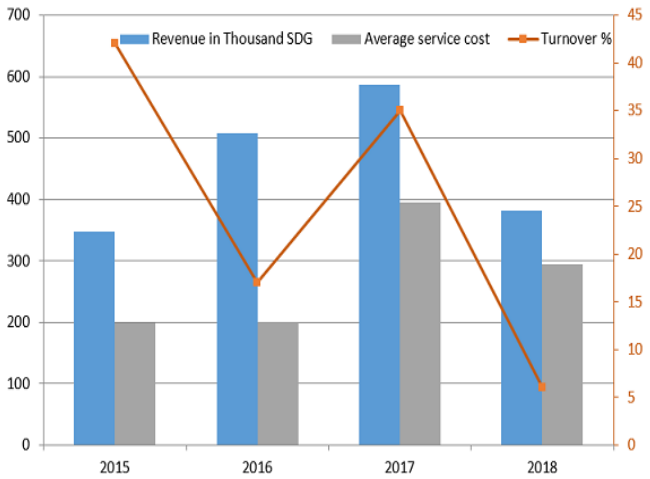

Fig. 4 Provider Y management dashboard

Fig. 4 shows the result of a drill down into provider Y focusing on Revenue, Average service cost, and Turnover between 2005 and 2018. These factors were selected to demonstrate the effectiveness of the framework in analyzing and exposing the correlation between them. Administrators explore trends through the years to try to explain their institutions' performance, for instance, the revenue drop in 2018, and turnover spike during 2015 and 2017. It's clear from Fig. 4 that from 2015 to 2016 the average service cost was consistently reasonably priced for patients at about 200 SDG. Staff turnover was extremely high in 2015 at around 47%, indicating that staff morale and job satisfaction were low. It's interesting to realize that during 2016 turnover dropped to around 17% without affecting the average service cost, and so provider Y was able to achieve its target of high revenue with less turnover. However, in 2017 competition in the healthcare market lead to high turnover and reductions in the average service cost and this was reflected in the provider's revenue. All these developments in turn lead to reducing turnover and improving Staff's job satisfaction as seen in the figure.

Table 1. Patients Frequency Per Department

Hospital Unit	Treated Patients		
	X	Y	Z
ER	387	2,399	1,099
Nephrologists	3	6	381
Anesthesiologist	6	56	-
Physiotherapy	62	-	-
Plastic surgery	168	3,326	-
Psychiatrist	309	-	16
Radiologist	364	37	15
Oncology	-	-	1,238
Ear, Nose & Throat	514	105	3,330
Dermatology	600	1,302	37
Ophthalmologist	620	-	-
Urologist	978	36,033	1,750
Obstetrician	1,360	11,137	3,753
Surgery	2,392	52,850	2,139
Cardiology	3,406	92	1,029
Endoscopy	3,835	31	700
Orthopedic	5,752	31,435	5,570
Neurologist	8,931	248	917
Pediatrician	12,392	1,964	4,528
Internal Medicine	17,154	8,592	8,748
Other	167	34	-
Patients Total	59,399	149,647	26,502

Switching to the second group of factors, i.e., services management, Table 1 provides an overview of the total number of services delivered to patients by all units of the three providers throughout the study period. This information serves hospital administrators by associating departmental patients' visits frequency to their revenue stream. In addition to the numbers, the table also shows a comparison of the available services by the provider. This availability information is valuable to healthcare regulators and the MOH, especially when combined with the providers' location and the region they serve. Suppliers would benefit from the information too, as it gives indications on where to market their medical equipment and consumables.

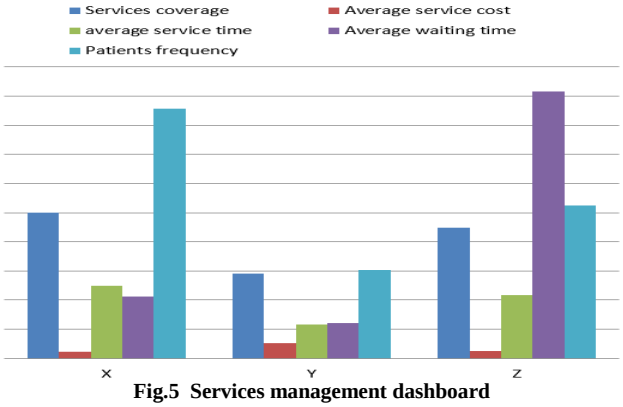

Fig.5 Services management dashboard

Fig.5 illustrates the services management factors including Service availability, Average service time, Patients frequency, Average service cost, and average waiting time. These factors and their many interrelationships suggest different things to different stakeholders. For example, from the provider administrators' perspective, service cost is a double-edged sword. Because when the cost of services is affordable to patients, they tend to have height frequencies, which in turn increases providers' revenue. This leads to providers having a competitive advantage, but simultaneously it reduces revenue and is likely to lower the quality of service. From this scenario, Fig.5, indicates that provider X delivers the most services, followed by provider Z, and then Y. The figure also shows that the average service cost for providers X and Z is lower than Y, while they deliver more services. This suggests that maybe provider Y administrators need to reevaluate the costing and pricing of their services, and possibly identify cost-saving measures. Additionally, Fig.5 indicates that a higher frequency of patients corresponds to higher average waiting times at the three providers while provider X in particular needs to pay close attention to its Average waiting time as it does not conform with the other two providers.

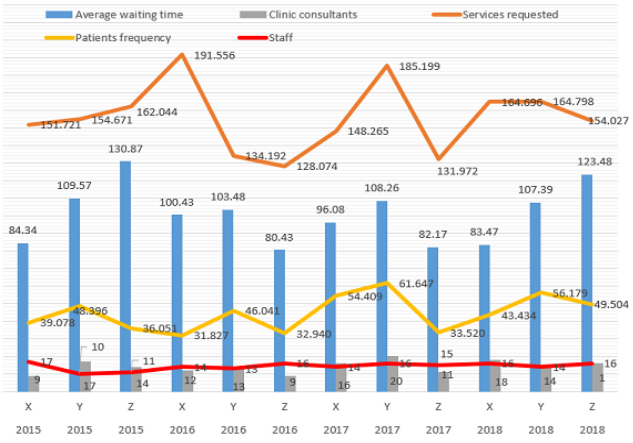

Fig. 6 Time management dashboards

The third category of factors is the time management group. This refers to providers' time management including service delivery time and patients' waiting time. Time management is critical as it directly impacts the providers' ultimate objective of patients' satisfaction. The units in Fig. 6 are as follows: Services requested is the total number of medical services requested in thousands, and Patient's frequency is in thousands too, while Average waiting time is in minutes, and Staff and Clinic consultants. The figure demonstrates the direct relationship between the Patient's frequency and both the Average waiting time and the services requested. Additionally, the relation between Average waiting time and the Staff is an inverse relation. While there is a direct relation between Clinic consultants and both Services requested and Patient's frequency. All these results derived from Fig. 6 provide plenty of information and insight into minimizing patients waiting time. For example, decisions and further analysis of the levels of staff and consultants at the provider as they related to patients' frequency and services requested.

The preceding results have demonstrated the effectiveness of the BI model in analyzing, correlating, and comparing different factors to expose their complex interrelationships and thus assist in improving healthcare services.

VI. SUMMARY AND FUTURE WORK

This study has investigated the adoption of BI technologies in enhancing the healthcare sector. It has developed a basic BI implementation model, identified essential factors for its adoption, and empirically examined its efficiency. The case study implementation utilized as a part of the validation focused on three of the core factors identified; provider, service, and time management.

The examination of the essential characteristic factors for BI adoption in healthcare has exposed the complexities of the sector and the need for improvements, while the identification of these factors is among the main outcomes of this study.

Moreover, the research results have demonstrated the efficiency of the proposed framework in providing decision-making information to healthcare stakeholders. This results in efficient decisions, improved stakeholders' satisfaction, and eventually enhancing the quality of the healthcare services provided. Furthermore, the research has shown that major prerequisites for BI implementation in healthcare are already available and there is wide support among stakeholders.

The future works involve extending the empirical studies to include other regions and the characterization of cloud computing and big data analysis involving healthcare BI.

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