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Original Article

Business Intelligence Dashboard in Healthcare: Lesson Learned

Ali Pakdaman[1], Mehrdad Karajizadeh[2], Mahdi Nasiri[3], Roxana Sharifian[4*]

[1]School of Management and Medical Information Sciences, Shiraz University of Medical Sciences, Shiraz, Iran
[2]Trauma Research Center, Shahid Rajaee (Emtiaz) Trauma Hospital, Shiraz University of Medical Sciences, Shiraz, Iran
[3]ToobaBigDataScience Company, Tehran, Iran
[4]Health Information Management, Health Human Resources Research Center, School of Management & Medical Information Sciences, Department of Health Information Management, Shiraz University of Medical Sciences, Shiraz, Iran

Abstract

Introduction: The present study aimed to investigate the impact of business intelligence dashboards on creating healthcare reports.

Methods: This is a cross-sectional study conducted in 2018 based on the type of data in occupational medical records of Shiraz Oil Company. First, based on non-structured interviews with occupational health authorities, the weaknesses of the existing health reporting system, the required indicators, and requirements of a business intelligence (BI) system were gathered. Then, according to the type of information available in the occupational medical records, business intelligence system including data warehouse and dashboards were implemented. Finally, to find out the effect of dashboards on the process of creating healthcare reports, the authors investigated the taskcomplexity, speed, and usability of the system using the cognitive walkthrough method, System Usability Scale (SUS), and Software Usability Measurement Inventory (SUMI) questionnaires.

Results: Findings indicated that the existing system was not user-friendly, was difficult to use and very slow, and required a lot of experience to work with. Results show that BI dashboards can tackle these problems. Moreover, the results of the usability evaluation of BI dashboards using the SUS and SUMI questionnaires were 90/100 and 67/73, respectively.

Conclusion: Based on the results, it can be concluded that the business intelligence dashboard can solve the problems of traditional reporting systems such as slowness and difficulty in producing analytical reports. Also, usability of BI dashboards was acceptable. Results indicated that BI dashboards could solve the mentioned problems, were much faster and user- friendlier than the existing system, and needed a little knowledge to work with. BI dashboard drastically decreases the problems of health managers in creating reports.

Keywords: Clinical decision support systems, Business intelligence, Clinical dashboard, Data analysis, Usability evaluation

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***Correspondence to:**
Roxana Sharifian,
Health Human Resources Research Center, Almas Building, Alley 29, Qasrodasht Ave, Shiraz, Iran
Tel: + 98 71 32340774
Email: sharifianr@sums.ac.ir

Introduction

A vast amount of medical data is generated every day (1). These health data need to be tracked and monitored for better management and control of diseases. Managing and controlling diseases is crucial for timely and appropriate measures to be taken in any community. If diseases are not monitored well, they cannot provide an overview of the current and past trends; hence, proper decision-making is disrupted, and readiness for future events is reduced. However, it is known that using a large amount of data to make decisions without using information technologies is difficult (2-4). One way to work with health data is to use business intelligence (BI) systems. BI with dashboards is a solution to working with huge amounts of data. Currently, BI is used in a variety of fields to integrate heterogeneous data types from different sources, do better data analysis and knowledge discovery (5-7), decrease errors, solve the problem of accessibility and availability of data (8), and perform a better data management and decision making (9-11).

Oil industry recognized the potential for significant health hazard. Therefore, monitoring health performance regularly is important (12). Moreover, development of business intelligent for reporting health performance in oil industry is essential. The authors conducted an applied study in the health sector of Shiraz Oil Company. They used DW/BI to help occupational health managers handle the staff's health. The problem with the current system of occupational health regarding the company is that access to the

required data is difficult. In addition, the process of making healthcare analytical reports is boring and time-consuming. The researchers aimed to design and develop a clinical dashboard for solving these problems. They attempted to investigate the impact of dashboards on solving the problems of slow report making and difficulty in access to information, and helping manage disease trends.

Materials and Methods

This is a cross-sectional study. First, there were some unstructured interviews with health safety engineer (HSE) experts and the occupational health managers of Shiraz Oil Company. All interviews were run in health sector of Shiraz Oil Company based on a guide form based on the current important report one by one; the interviews were recorded by voice recorder. Each review lasted about 45 minutes. Prior to the interview, the researcher obtained consent from the participants. Health performance indicator was classified based on the department of health sector and users' requirement.

All the data available in occupational medical records (OMR) of Fars Province oil industry staff are the same as OMR in other companies. The authors used HSE indicators to make reports in dashboards. The BI has a *data warehouse (DW) and* contains a *data mart* that includes OMR data. To achieve a good performance, researchers built a *DW* based on Kimball's method (13).

Information extracted from the *DW* was shown in the dashboards. Dashboards were built assuming the simplicity of information provision. Diseases have been identified in dashboards using the traffic light method (TLM). TLM shows information in different colors. Information indicating normal situations was in green, and abnormal situations were in a spectrum of yellow to red. Information was shown in a range of yellow to red. Emergencies with high priority were in the red color. Each dashboard had filters and parameters defining which data were shown in it.

All the dashboards were evaluated to find the answer to three questions:

1. How complex is the process of report-making from the point of view of the end user?

2. Can BI save the managers' time compared to the traditional reporting approach? A

3. How satisfied are the health managers, as the real users of the system?

We used usability evaluation which is similar to the one introduced in Kushniruk and Patel's study (14) with some minor changes. First of all, a cognitive walkthrough (14) was done to find out the differences in the complexity of the process of report-making between the new and old systems. All users had good prior knowledge of using computer. The only thing the researchers did was quickly teach them how to use the dashboards in an hour. All opinions were written down by the users while they were using the system.

Then, the user-friendliness, learnability, controllability, and overall user satisfaction of the system were assessed. To this end, a usability evaluation with two questionnaires was done. *SUS*, a simple, valid, and reliable (15) questionnaire with 10 items, was used to quickly check the usability of the dashboards. Then, the second round of evaluation was done using *SUMI*, a valid and reliable comprehensive questionnaire with 52 items (16, 17) after a month.

Results

Requirement Analysis

The results showed the importance of reporting the health status and disease trends, existing problems of the current report-making process, and requirements of reporting system. The results of the interviews are shown in Table 1.

Table 1: Requirement analysis of health performance dashboard in health sector of oil industry

Important items	Details
Advantages and disadvantages of the current system	Disadvantages: • The system is very slow • Using the system is not satisfactory • Working with the system needs an experienced user • Retrieving data is not easy and it is time-consuming Advantages: Computerized data can be retrieved
Needed report indicator	Prevalence and incidence of diseases [20, 21] based on HSE standard reporting format. Reporting occupational diseases has a high priority.
Availability of data	All sections of personal occupational medical records including clinical reports, laboratory tests results, medical examination reports, psychological test results, doctor notes, and demographic information are available
Requested health reports	Reports needed based on HSE standards and its priorities.
Time priority of reports	• Yearly reports needed • Some weekly, monthly, or daily reports on clinical data may be needed.

Develop Dashboards

Dashboards were designed for one-click filtration. Therefore, by clicking on a specific part of each diagram on a dashboard, all information on that dashboard would be filtered and updated. Two examples of dashboard are shown in Figures 1 and 2.

Figure 2 shows one of the most comprehensive dashboards in the system. It visualizes vital information about occupational diseases and problems in the workplace. The top row demonstrates the static filters which can filter diagrams in the dashboard accordingly. The dashboard can report three major psychological problems which are anxiety, stress, and depression. The left part of the middle row shows the ratio of diseases or problems. The right side of this row reveals the trend of diseases in the company.

A cognitive walkthrough indicates the steps needed to create a single analytic report by the dashboard versus the typical system. As shown in Table 2, the process of making a single report on the prevalence of depression (as an example of a report) was simpler when the dashboard was used compared to when the old method was used. Checking the changes in the workplace caused by making analytical reports of the trends of diseases suggested a high level of stress and pressure before using the dashboards. Authorities of the oil company and HSE experts reported that making these types of reports was boring, and this was shown in the results of the walkthrough for the

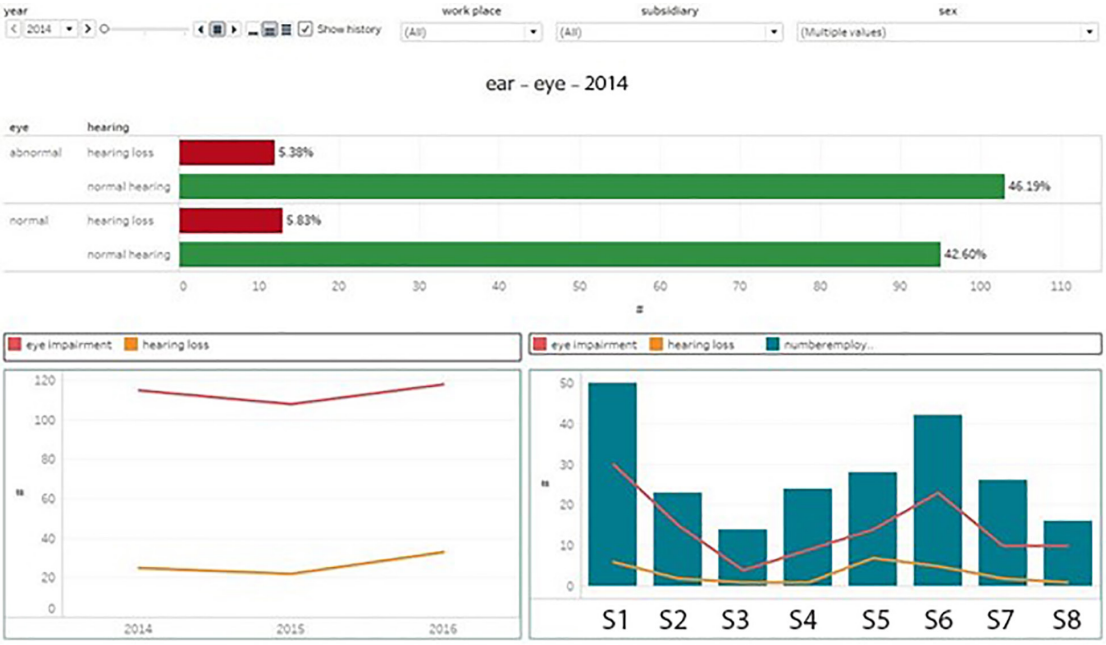

Figure 1: Dashboard of the eye and hearing impairment. Data is for publication and is not real.

Figure 2: Dashboard of the ratio and trends of diseases. Data is for publication and is not real.

Table 2: Cognitive walkthrough results

Typical system	Dashboards
Goal: create a report on prevalence of depression in subsidiaries of oil company	
Action: select a data source	Action: go to appropriate dashboard
1^{st} subgoal: get number of employees with depression in any subsidiaries	1^{st} subgoal: get number of employees with depression in any subsidiaries
Action: make the right query	Action: set the right filters or parameters
System response: result is in form of a number as number of cases with depression	Action: click on the right diagram and select export
Action: export results to excel	System response: diagram of the prevalence of depression will be created in the form of pdf or word document
Problem: making queries is time consuming a user experienced using the system	2^{nd} subgoal: report the details of medical and need records of employees with depression
2^{nd} subgoal: get the number of employees in each subsidiaries	Action: right-click on the diagram of prevalence of depression
Action: make the right query to get number of employees	Action: select the details from opened sub- menu
System response: result is the number of employees	Action: export or copy data to Excel
Problem: making query is time- consuming and need an experienced user	
Action: export the results to Excel	
Action: make the report based on the equation of prevalence of diseases	

typical system. It takes a long time to create a query and get appropriate data from the system. Exporting data to Excel and PowerPoint is still a repeated action that occurs for every single report. Even if the reports are the same since the data were changed, these steps must have been repeated. Another point to consider is that HSE staff (users of the system) must prepare a huge number of assessment reports at the end of each year. They reported that they were under high pressure to prepare the reports in the requested time. Dashboards made this process a lot easier and more satisfying. Users reported low levels of pressure and stress when preparing the assessment reports since they could easily do it by using the dashboards.

Usability

Two rounds of evaluation were conducted to determine the usability of the dashboards. First, the usability by the simple SUS questionnaire was evaluated; then to get more details (filled by 5 users), it was done again with the SUMI questionnaire (SUMI filled by 10 users). We recorded the opinions of the users and checked the differences found in the working process.

Statistical analysis of the first round of evaluation is shown in Tables 3 and 4. The confidence interval must be calculated to have a better idea of the usability of the dashboards.

Confident interval=MOE (margin of error)±mean
MOE=standard error $*$ (t 0.05, n–1), where t 0.05 is the t-score at the confidence interval of 95%.
MOE=1.97 $*$ 2.23=4.3931

The confidence interval of the usability score was 90.9±4.3931, and the learnability of the dashboards was 9.2/10. Furthermore, the likelihood of recommending the (*LTR*) score was about 9 of 10.

Sumi scales (which is more comprehensive than SUS), with a 95% of confidence interval, are demonstrated in Figure 3. Results revealed that the users were satisfied with the use of the dashboards and they felt it was efficient and made work easier.

Table 3: Statistical analysis of the first round of evaluation by SUS questionnaire

	Min	Max	Mean	Std. error	Std. deviation	Variance	Mode	Median
Score	80	100	90.9	1.97	6.545	42.841	92.5	92.5

Table 4: Statistical analysis of the results of the second round of evaluation by SUMI questionnaire

	Mean	Std. Dev	Median	IQR	Min	Max
Global	62.40	2.99	62.5	5.0	58	67
Efficiency	67.10	5.67	68	9.0	59	73
Affect	62.00	4.16	63.0	6.0	54	66
Helpfulness	63.10	4.65	63.5	7.0	56	68
Controllability	65.40	3.81	66.0	7.0	61	69
Learnability	64.30	4.22	66.0	4.0	55	70

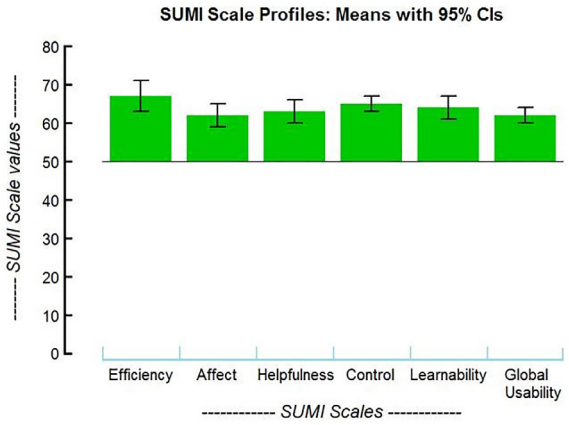

Figure 3: 95% confident interval of the usability evaluation by SUMI

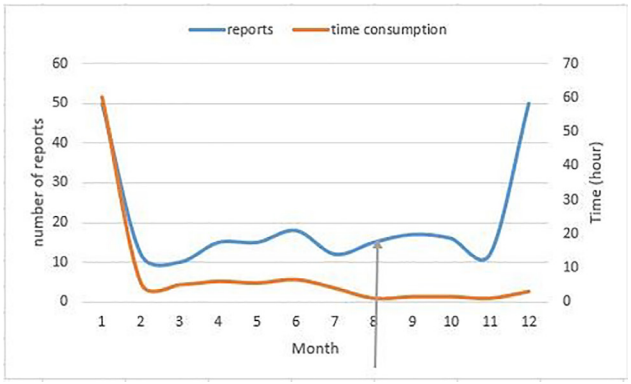

Figure 4: The number of reports created and time spent on them. The left side of the indicator shows the time spent to create report with the old method, and the right side shows the time needed to create reports with dashboards.

The number of reports and the time spent to create the requested reports were recorded for the last one year. Once a year, all subsidiaries of the oil company checked the health status of their staff. To this end, they requested huge number of analytical reports on the trends of diseases in their companies. At other times of the year, HSE experts needed some routine reports. Typically, making a report takes an average of 30 minutes to be prepared. After implementing the dashboards, the time spent to make reports was reduced by up to 10 times (Figure 4).

Discussion

The authors built some dashboards for monitoring the trends of the diseases in a company. The results indicated the importance of dashboards in healthcare management. Various studies showed the problem of huge inconsistent clinical data, the benefits of summarization, and its presentation in a simple way (4). Dashboards are good ways of visualizing the data simply. They show information to reduce the time of accessing data and making a decision in various clinical fields like diabetes care (18), radiology (19), maternity care (20, 21), and other health-related issues (22) The results of this study, as a case for the management of occupational diseases, revealed that the time spent for accessing data and creating clinical reports considerably decreased by dashboards, which is consistent with prior studies (23). The problem of health data quality and lack of integrated data which is important in the healthcare industry all around the world (22) was solved in our study as well. This was done by creating a DW that collects all the data together in the correct and precise format for use in the dashboard. DW ensures the accuracy and quality of the reports. The researchers can expect that the quality of the data provided along with the quality of information help to improve decision-making on this system. Usability scores in both rounds of the evaluation indicated that dashboards were usable, efficient, and effective and the users were satisfied with using them. Some psychological studies revealed that visualizing data was a pleasing way to transfer messages (24), identify trends, and monitor diseases (25). In addition, using charts is one of the best ways of visualizing easily understandable health data (26, 27). The dashboards in this study exhibit report in the form of bar charts which is one the best forms of visualization according to previous research. This can explain why users stated the dashboard's reports were easy to understand and satisfactory to work with, and that they felt comfortable using them. It is also vital to show the trends of the disease based on the present and past. As Lee's research results (28) illustrated, satisfaction of the users with the system can be an inspiration for its use. Usability evaluation showed that users were comfortable using the dashboards; hence, the authors expect that users will continue using the system. Stakeholders reported that analytical reporting with dashboards was simple and effective. The typical time that the authorities of occupational health must wait to receive these types of reports without dashboards was up to a month after they requested them. However, it is amazing that after using this system, they got real-time reports 24/7, and they could get paper-based reports in one day. Some studies showed this time reduction in the number of the required clicks (18). This is consistent with the results of this study. Therefore, the problems of availability of data, adequate delivery of the analytical reports, pressure, and stress at work to prepare the reports, and difficulty of accessing data at the right time were solved with a great system of reporting in the form of dashboards. Besides, dashboards help to make faster decisions by displaying real-time reports. This is an important characteristic when people are

concerned with the vital situation of health status in the population.

The system needs more time to detect changes occurring in the hospital workflow and adapt to the new system. Moreover, this system is designed for monitoring the trends of occupational diseases. It is not used by physicians in the process of examination of the participants. The findings of this study were limited concerning displaying how fast and efficient a dashboard can show a holistic view of health and diseases in the population and deliver an accurate foundation to decision-makers. This is to find priorities in health status based on the trend of diseases.

The researchers created DW and clinical dashboards to monitor the trends of diseases in an organization as a case study. Checking changes made by the system at the time of creating health analytical reports and the level of stress and pressure on stakeholders to prepare these types of reports to decide about the diseases in the company, and doing a usability evaluation of dashboards gave the authors a comprehensive view about this type of system. Findings indicate that dashboards are visualizing systems that provide the information needed impressively: they are created one time and used every day. They can competently present information, so that everyone understands the message behind them. Using dashboards to visualize the important information about occupational diseases and health status was beneficial and the users were highly satisfied. An important characteristic of dashboards is that they are efficient, effective, easy to learn and control and reduce the time of reporting and decision making. Managers could filter their required information with just one click; they could prepare proper reports in a short time with no trouble. In addition, dashboards help the users to know the health status of the population in a short time. It seems that visualizing health status in dashboards is a good way of providing information to doctors and decision-makers on occupational health. The authors expect that dashboards would make it easier to check out the health conditions of a large number of people.

Conclusion

The results of this study clearly showed that the business intelligence dashboard can solve the problems of traditional reporting systems such as slowness and difficulty in producing analytical reports. Also, usability of BI dashboards was acceptable. Results indicate that BI dashboards can solve mentioned problems; they are much faster and user friendlier than the existing system and need a little knowledge to work with. BI dashboard drastically decreases the problems of health managers to create reports. In our future research, we intend to concentrate on developing BI dashboard for monitoring health performance indicators in health sector of oil industry in national and international scale.

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Authors' Contribution

AL: conceptual and design study, data acquisition, data analysis, drafted and revision paper. MK: contributed to conceiving and design of the study, interpretation of data, commented on drafts, and made significant revisions to the paper. MN: contributed to the design of the study, interpretation of data, commented on the draft, and made significant revisions to the paper. RSH: contributed to the design of the study, statistical analysis, commented on drafts, and made significant revisions to the paper.

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Ethical Approval

This study was approved by institutional review board of Shiraz University of Medical Sciences (Approval ID: IR.SUMS.REC.1397.863).

Consent for Publication: Not applicable.

Conflict of Interest: None declared.

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