



Improving Health Care Management in Hospitals Through a Productivity Dashboard

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Abstract

Health information systems have been developed to help hospital managers steer daily operations, including key performance indicators (KPIs) for monitoring on a time-aggregated basis. Yet, current literature lacks in proposals of productivity dashboards to assist hospitals stakeholders. This research focuses on two related problems: (1) hospital organizations need access to productivity information to improve access to services; and (2) managers need productivity information to optimize resource allocation. This research consists in the development of dashboards to monitor information obtained from a hospital organization to support decision makers. To develop and evaluate the productivity dashboard, the Design Science Research (DSR) methodology was adopted. The dashboard was evaluated by stakeholders of a large Portuguese hospital who contributed to iteratively improving its design toward a useful decision support tool. Additionally, it was ascertained that monitoring productivity needs more study and that the dashboards on these themes are valuable assets at a monitoring level and subsequent decision-making process.

Keywords Health information systems · Business intelligence · Dashboard · Hospital management · KPI

Introduction

Healthcare is a key sector that calls for efficiency to improve its impact on countries economy [1]. Nevertheless, hospitals need to deal with an unstable environment encompassing external factors [2]. Therefore, to improve their performance [3] they need to measure and evaluate to support daily operations as well as to define strategies [1].

The impact of the introduction of information and communications technology (ICTs) in the multifaceted health sector is well known and recognized [4]. There is a key relation between the level of ICTs adoption, the level of financial well-being and the level of productivity of healthcare organizations [5]. Business Intelligence (BI) is an umbrella that encompasses all information systems (IS) devoted to provide

decision support by compiling and aggregating the raw data retrieved from the operational systems [6]. BI tools such as dashboards are designed to provide valuable managerial information that helps in supporting decisions. When backed by a business-oriented BI infrastructure, those tools enable healthcare managers to measure performance, monitor KPIs by preventing deviations, understand undesirable behaviors and redefine objectives [7]. The dashboards present information in the form of KPIs that are chosen based on the organizations strategy [8] and their visualization is a crucial factor so that stakeholders can obtain the information to make the necessary decisions [9]. Due to the complexity of the decision process it is necessary to make available techniques such as drill down which, when necessary, allow a more detailed analysis of the information and thus provide data to justify the decision [10, 11]. Dashboards are very useful tools for measuring productivity in organizations [12], an example of this applicability in marketing where dashboards are created with the main KPI's that help organizations analyze their customers' consumption activities [13].

The medical community is known for pioneering in several areas including technology. Yet, such innovation does not extend to improve patient care using computer systems at the management level of hospitals [14]. Furthermore, productivity

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measurement has always presented enormous complexity because it is more about people wellbeing rather about profit [15]. Nevertheless, there is an increasing need for healthcare organizations to adopt dashboards to provide information about the quality of services provided to patients [16]. However, healthcare organizations still struggling to adopt the most suitable decision-making tools [17] regarding productivity information [18]. Therefore, this study proposes a dashboard that enables healthcare stakeholders to be able to perform an analysis, evaluation and monitoring of productivity KPIs to support decision making.

Literature review

Health information

The healthcare industry concerns for the safety of the citizens and it is one of the most complex sectors, due to the high number of stakeholders [19]. The provision of quality healthcare requires the accomplishment of the interconnection of patient information which is found in several different sources and makes it available to all healthcare professionals and the patients [20]. Hospitals have a huge amount of data stored over decades and much more has been collected in the new digital era. With technological developments at the level of EHRs or other data sources, made it possible to analyze various types of financial information, laboratory data and electronic patient records [21]. Healthcare managers are provided with a significant amount of information to improve the well-being and the future of organizations, but this information overload leads professionals to do everything they can to simplify the obtaining data [20].

ICTs adoption in healthcare face serious obstacles, since often these are introduced into hospitals as pilot projects which have not been tailor-made for doctors, and this is the main reason that doctors state to justify the lack of adopting such systems [14]. Yet, hospitals that have successfully adopted ICTs can take advantage of the vast amount of data produced and collected to help support both their daily operations and strategic decisions [21]. Thus, successful hospitals assume ICTs as assets to achieve efficiency and effectiveness, which translates into both an improvement of healthcare services as well as transparency to facilitate auditability in such a critical industry [22].

Dashboards as tools to improve productivity in health

Dashboards enable to monitor an organization's performance, with current literature acknowledging several benefits from its adoption (Table 1). Therefore, these are key tools for health organizations. Productivity is a critical aspect for health systems' performance, which can be defined by the physical

Table 1 Benefits/Drawbacks of dashboard

Benefits of Dashboards	References
Process optimization	[7, 23–28]
Improve information access	[7, 23, 24, 26, 29, 30]
Increased performance	[28, 30–32]
Improve knowledge	[24]
Drawbacks of Dashboards	References
Training needs	[26, 32, 33]
Barriers to Technology	[28, 31, 32]
Ununiform infrastructure	[34]

inputs used (labor, capital, and supplies) to achieve a certain level of health outcomes in the treatment of a specific disease [35]. Thus, measuring productivity is essential to achieve a more efficient allocation of resources in a hospital organization [18]. As a result, the role of dashboards has been increasing in the health sector. Nevertheless, dashboards need to achieve a balance between the visual aspects and the contained information to be valuable for decision support [36].

The idealization of the visual design of a dashboard is a determinant factor for its success or failure. The important challenge is to make use of the visualization to facilitate extracting the information contained in the dashboard [12]. Also, a dashboard should provide unambiguous information, which should not be prone to misinterpretations [29]. The information which is obtained through techniques enables value creation [33].

Some authors argue that detailing is extremely important to dashboards. Even when a dashboard is correctly designed, “a single page is rarely sufficient to present all the relevant performance metrics and therefore the dashboard must have a drill down capability” [10]. A drill down within a dashboard provides stakeholders with intelligent analysis capabilities due to the level of detail they can achieve through filtering and zooming [7, 27].

Table 2 Main related keywords highlighted in the articles

Main Key Words	References	Total
Dashboard	[7, 11, 37]–[36, 38]–[26, 28, 31, 32, 34]	17
Healthcare	[7, 23, 25, 30, 36, 39–42]	9
Hospital Units	[11, 26, 28, 37, 40, 41]–[43]	9
Business Intelligence	[23, 25, 36, 38, 39, 44, 45]	7
Decisions Making	[24]–[26, 34, 46, 47]	6
Data Visualization	[25, 28, 34, 36, 48, 49]	6
Data	[25, 26, 44, 50]	4
Quality	[31, 51]–[52]	4

Table 3 Concept-centric dashboard in healthcare

Healthcare Area	Articles	Displays dashboard	BSC ^a	Drill down	Visualization
Clinical	[40]	•		•	
	[53]	•			
	[49]	•			•
Emergency Department	[54]	•			
	[29]	•			•
	[34]	•		•	•
	[30]	•			•
	[43]	•			
	[38]	•		•	
	[7]		•	•	
Management & Logistics	[25]	•	•		•
	[28]	•		•	
	[23]	•			•
	[39]	•		•	•
	[52]				•
	[36]	•		•	•
	[48]	•			•
	[51]	•			
	[44]	•		•	•
	[47]	•			
	[55]	•			
Information system					
Pneumology Department	[56]	•			
	[57]	•			•
Nursing Department	[31]	•			
	[41]	•		•	
Surgery Department	[50]	•			
	[42]	•			
	[26]	•		•	
	[45]	•	•		•
	[58]		•	•	•
Pediatric Department	[37]				
Public healthcare	[24]	•		•	•
	[46]	•			•
	[59]	•			
Radiology Department	[32]	•			
	[60]	•			
	[27]	•	•		•

^a Articles where the Balanced Scorecard (BSC) was implemented

Although the benefits for organizations adopting dashboards, there are also inherent disadvantages acknowledged in existing literature, mostly related to technology adoption and inadequate infrastructure (Table 1).

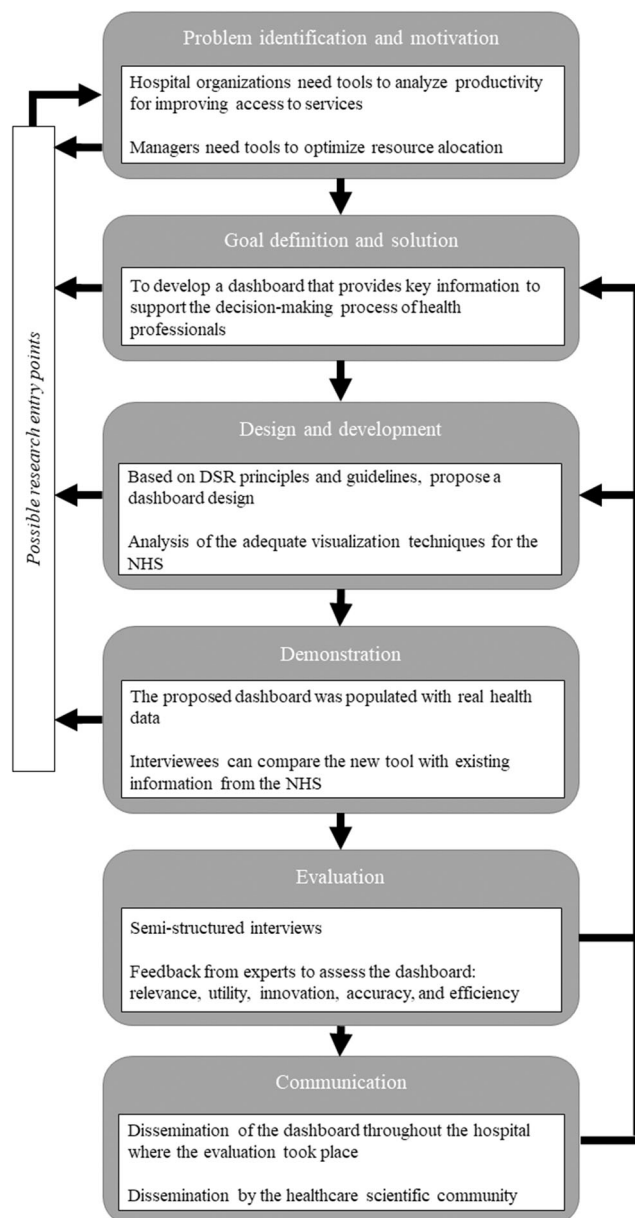
Related work

Extensive literature exists in health IS adoption of dashboards. As such, a thorough search through academic databases identified 192 articles. A first reading of titles and

abstracts resulted in exclusion of 101. Such removal was justified since 45 documents addressed the issue of health but did not focus on dashboards, while 6 documents addressed other domains besides health, 20 were duplicates, and finally, 30 articles focused only on KPIs and/or balanced scorecard (BSC). Both (KPIs/BSC) are relevant concepts within dashboards, yet our research is focused on dashboard design. After the first selection, 91 documents were classified as potential articles to be included in the literature review (LR). In a second analysis, 41 articles

Table 4 DSR principles applied to our study

DSR Principles	Explanation
Abstraction	The research consists of the development of dashboards to monitor the information obtained from the operation of a hospital unit with the mission of being able to support the various stakeholders in the decision phase. Thus, the authors follow indicators from the National Health Service (NHS), which is the entity by which the Portuguese Government regulates health in Portugal. The dashboard was validated in a large Portuguese hospital.
Originality	The proposed artefact is not in the BoK.
Justification	The justification for the panel is based on the methods proposed for its evaluation. Qualitative interviews were conducted with health specialists and with some of the main stakeholders of the proposed artefact. With this contribution it was possible to improve several aspects and add value to the artefact.
Benefit	The development of dashboards which allow obtaining in a single location the macro production and productivity information of a hospital organization that allows decision makers to obtain useful information so that they can make the right decisions in a timely manner. This added value can help improve the performance of organizations.

**Fig. 1** DSR adapted to our approach

were excluded, since they did not focus in the dashboard design itself, although those mentioned dashboards. As a result, an additional of 10 articles were discarded, leaving a total of 38 articles. Table 2 highlights the most frequent keywords used in the articles. The unveiled body of knowledge (BoK) shows a steady increase on the subject from 2010 to the present, highlighting the increasing relevance of dashboards in healthcare. Also, most of studies are from the USA (20 articles).

Table 3 shows a concept-centric view of the encompassed BoK focused on the research areas addressed. Hain et al. [37] conducted a literature review on pediatrics, thus they neither addressed dashboard presentations nor BSC nor visualization techniques/drill down, although they focused on productivity. Research spreads through 14 different areas covered by the 38 articles. It should be noted that radiology, emergency and surgery are the departments where there is research in performance improvement and analysis of quality of service.

Interestingly, only 13 articles studied drill down. Yet, according to Park et al. [26], drill down is a feature of extreme importance which adds more value to the dashboard (corroborated by Baskket et al. [10]). Finally, most of the 38 articles urge for the continued efforts in studying and improving dashboards as tools to improve productivity in hospitals.

The unfolded state of the art demonstrates that the health industry is complex, and this complexity gives rise to a high number of data. Such data, when treated and analyzed, is of value for hospital organizations, helping to raise awareness for these organizations' needs. Thus, the role of HIS in hospitals is increasingly influential for improving decisions. The dashboard is a tool that can be useful to provide the information in a transparent and easy to analyze form and accelerates the phase of the decision process. In the economy as well as in hospital organizations the concern with productivity is having an increasing prominence. The use of dashboards to help meet this growing need is an even better bet supported by visualization and drill down techniques that provide an ability to both

Table 5 Rules for using colors [62]

Rule	Description of rules
Rule 1	If you want different objects of the same color in a table or graph to look the same, make sure that the background the color that surrounds them is consistent.
Rule 2	If you want objects in a table or graph to be easily seen, use a background color that contrasts sufficiently with the object.
Rule 3	Use color only when needed to serve a specific communication goal.
Rule 4	Use different colors only when they correspond to differences of meaning in the data.
Rule 5	Use soft, natural colors to display most information and bright and/or dark colors to highlight information that requires greater attention.
Rule 6	When using color to encode a sequential range of quantitative values, stick with a single hue (or a small set of closely related hues) and vary intensity from pale colors for lower values to increasingly darker and brighter colors for higher values.
Rule 7	Non-data components of tables and graphs should be displayed just visibly enough to perform their role, but no more so, for excessive salience could cause them to distract attention from the data.
Rule 8	To guarantee that most people who are color blind can distinguish groups of data that are color coded, avoid using a combination of red and green in the same display.
Rule 9	Avoid using visual effects in graphs.

optimize analysis and the possibility of deepening the information needed.

Methodology

This study adopted the Design Science Research (DSR) methodology. Its premise is to design, build and evaluate the proposed dashboard, which is the developed artifact, according to DSR [61]. As such, this research follows the principles presented in Table 4. The principles of DSR are grounded in the engineering of artificial things and IS are a perfect example of artificial systems where research requires implementing a tool. Figure 1 shows how the DSR was adapted for our study.

The use of colors in a dashboard can be a plus, but for this to happen it is necessary to choose them according to known rules, as shown in Table 5.

The principles of Gestalt's visual perception (Table 6) help to understand which elements are crucial and which are not for the transmission of information and which

elements are pollution and/or accessories [63]. In the evaluation phase of DSR of each proposal for dashboard improvements presented in each iteration, a questionnaire was carried out. The corresponding questions which guided semi-structured interviews are highlighted in Table 7, aiming to understand both negative and positive aspects, as well as to identify improvements. Proposed improvements are classified under three different categories (key elements in any dashboard): visualization, information and navigation. Therefore, stakeholders can answer their questions about indicators in any of those three categories, which may trigger the development of new indicators or upgrading of the existing ones [33, 43]. The information provided is critical for stakeholders, since they make decisions based on the shown indicators [64]. Finally, navigability needs to be treated very carefully so as not to create an exaggerated overload of components, contents and tabs to dashboards. Thus, navigation elements should only provide and be used to facilitate the necessary navigation to the dashboards without making them too confusing [65].

Table 6 Gestalt's principles

Principles	Description of the principles
Proximity	Objects that are physically close are perceived as a group due to their closeness [62].
Similarity	Objects that have any of the following characteristics such as color, shape, size, or orientation are presumed to be realigned or belong to a group [63].
Enclosure	Objects that have any of the following characteristics, such as color, shape, size, or orientation, are considered to be related or part of the same group [62].
Closure	Graphs without borders, without shaded background are also perceived as complete Nussbaumer Knaflic guidelines visualization [63].
Continuity	This principle is very similar to that of the Closure when an object is analyzed, the human eye seeks the smoothest and most natural way, creating continuity as far as this continuity can exist [63].
Connection	When objects are interconnected they create an idea of a group [62].

Table 7 Key evaluation questions

Questions
What are the negative aspects of the proposed dashboard?
What are the positive aspects of the proposed dashboard?
What improvement proposals do you intend to make regarding the proposed dashboard?

Proposal and evaluation

The proposed dashboard was the subject of an iterative DSR procedure, using four cyclic iterations of semi-structured interviews with the health professionals from a large Portuguese hospital which serves a direct population of more than 330 k inhabitants, and has received more than 280 k patients and 15 k surgeries in 2016, with a total medical staff of almost 400 MDs and almost a thousand nurses. Each interview resulted in a DSR iteration that helped to validate, consolidate, and improve the dashboard. Table 8 presents the interviewees who contributed in this process. All the interviewees had more than 20 years of experience in the health area. In addition, their experience is not restricted to a single hospital organization or just to one sector, the interviewees, for the most part, have experience in both sectors. In average the interviews lasted one hour and a half. Each interview was divided in two phases: in the first, the interviewee tested the dashboard, including the presentation and navigation items, while in the second, the interviewee responded to the questionnaire.

In the next four subsections, the authors develop each of the four iterations used to improve and tune the dashboard. Each of those subsections is further divided into more sub-subsections to reflect the DSR phases. Hence, in the first iteration, an initial proposal is developed based on existing healthcare literature (Fig. 1), which is then used for demonstration and to be evaluated. In the remaining three iterations, the dashboard is tuned by improving its design through the feedback gathered from the previous iteration.

First DSR iteration

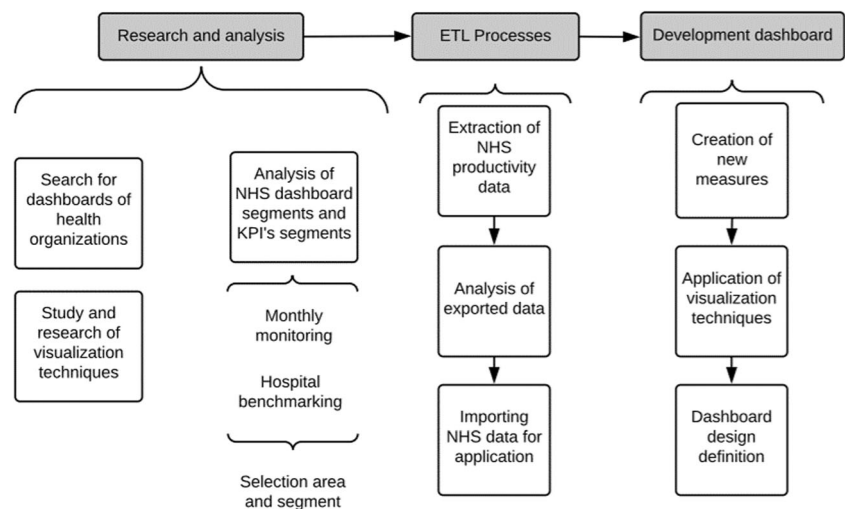
Initial proposal

The first iteration needs a solid baseline for producing a realistic first dashboard proposal. Thus, the authors identified two critical phases for this iteration: research and analysis, and ETL (extract, transform, load) processes (Fig. 2).

The research and analysis phase was undertook to produce a first version which, although still being a draft, it needed to meet critical concerns from the stakeholders. As such, it was divided into two distinct stages. The first was devoted to researching and analyzing the existing supply of dashboards for health organizations worldwide. Then, a survey on visualization techniques was conducted to assess how those were being adopted in health organizations. Finally, an exhaustive analysis was conducted to the NHS site to understand which KPIs were adopted from a productivity perspective. The

Table 8 Interviewees' characterization

DSR Iteration	Gender	Age	Department	Role	Years of experience		Number of institutions	Public	Private	Graduation	Post-Graduate Habilitations
					Health sector	Hospital under study					
1	Female	44	Planning, Studies, Analysis and Management Control Service	Superior technique	23	10	3	2	1	- Human Resources Management	- Labor Law
2	Female	41	Surgery Area	Administrative Hospital	20	11	3	3	0	- Human Resources Management	- Hospital Administration
3	Female	51	Planning, Studies, Analysis and Management Control Service	Service Director	30	8	7	6	1	- Nurse - Computer Science and Business Management	- Management of Health Services - Business Administration
4	Male	54	Information Systems Management Service	IT Director	36	8	4	4	0	-Computer Science	-Bachelor of Engineering in Computer Science
Total					109	37	17	15	2	N/A	
Average					27,25	9,25	4,25	3,75	0,5		

Fig. 2 Initial proposal development

Portuguese State has tried to make health data as transparent as possible, both for the average user and for the healthcare professional. As such, on their website, there is a webpage on “transparency” where each KPI is detailed for both monthly monitoring and benchmarking.

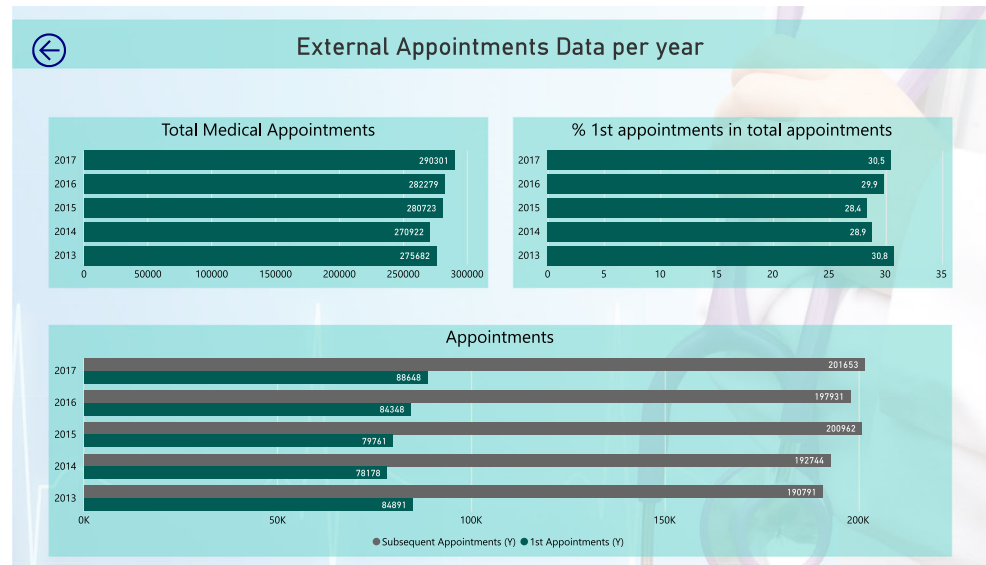
Information on the NHS website is provided by public hospitals on a quarterly basis. Monitoring information is used in benchmarking, that is, the current KPIs are computed based on the indicators in the monthly monitoring. Accordingly, the data used for feeding the proposed dashboard was extracted from the monthly monitoring information freely available to the public, including detailed data about the specific hospital where the interviewees work.

The development of the dashboard required real data to enable a realistic evaluation by the interviewees. Therefore, the authors performed an ETL process from several data sources to build a consistent data mart populated by relevant information from the hospital.

For developing the initial dashboard, the authors followed design principles related to visualization techniques which are described by Few [62] and Wexler et al. [66]. Thus, a left panel was created on the dashboard by considering KPIs identified in current health literature for productivity of the following areas: surgery, internally, external consultations and emergencies. The segments present in the dashboard are defined in a decree-law by the Portuguese State and are used by the NHS in the benchmarking and in the monthly monitoring that this

**Fig. 3** The monthly perspective of external appointments (1st iteration)

Fig. 4 The annual perspective of external appointments (1st iteration)



entity provides to hospital organizations. Therefore, this initial version enables an initial assessment and familiarization of the interviewees with the information provided, helping to enhance their feedback in the following iterations.

Demonstration

The initial dashboard presented was designed by considering navigability, information exhibited, types of graphics and functionalities that enable a detailed analysis of the KPIs.

At the level of the dashboard structure, it is divided into three types of overall and applied views whenever the data foresee, annual, monthly and target. These perspectives are presented whenever the data allow. In the monthly perspective (Fig. 3), it is possible to verify that it is divided into two headers and detail areas. The header identifies the title of the segment that is being viewed, the return button and filtering per year is. The detail

area is divided in two, and on the left side we have the KPIs with annual values and compared with the homologous year, and on the right side, graphs are shown with the monthly distribution of KPIs and other analysis that can be used by the decision-makers. Also, in these graphs there is a comparison of current year with the homologous year.

In Fig. 3, it is noticeable that the authors followed the subsequent principles of Gestalt: proximity similarity, closing, and connection. These forms are also followed in the views (Annual and Target). Throughout the dashboard the guidelines of the colors rule, rules 4 and 5 (Table 5) are the ones that stand out more whereas the colors only change for different subjects and the use of more attractive colors for the KPIs. In Fig. 4 when referring to the annual information, the color guidelines are also visible.

Finally, Fig. 5 shows only those indicators that have a defined goal in the contract program (annual agreements

Fig. 5 The annual target of external appointments (1st iteration)

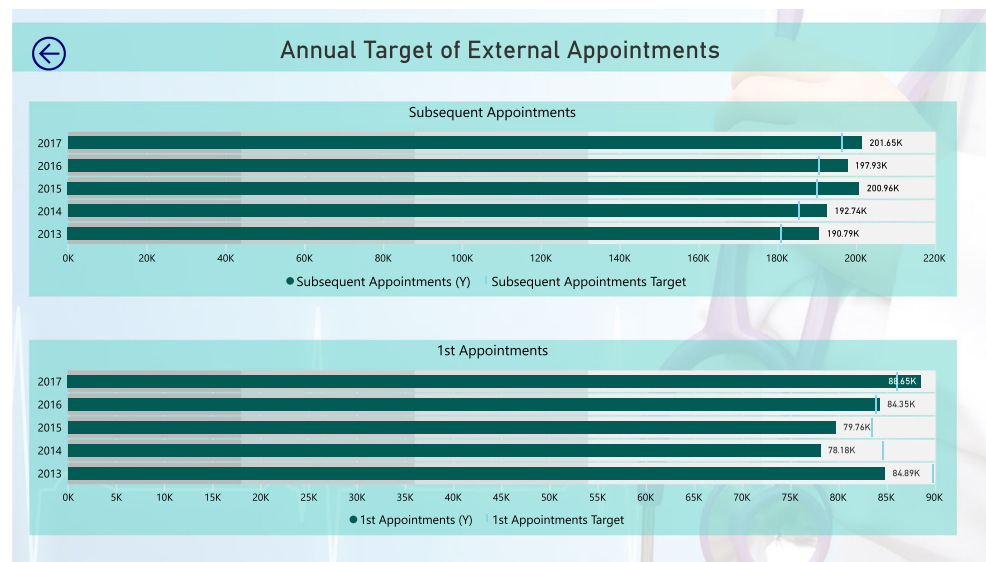


Table 9 Evaluation of the prototype (1st iteration)

	ID	Synthesis
Pros	P1.1	“The dashboard is useful and easy to read as it allows an overview of the data of each segment.”
	P1.2	“The choice of graphics components is well achieved.”
	P1.3	“The information on the dashboard only concerns the hospital.”
Cons	C1.1	“The data present in the dashboard should be organized from the more general to the more specific.”
	C1.2	“The background color of the graphics should be changed to improve the reading.”
Proposed Improvements	PI1.1	“Creation of a graphical component of KPIs that allows the comparison of the current year with the homologous, as well as the current year and the target.”
	PI1.2	“Improvement in the organization of the information of KPI’s plus macro for the more micro.”
	PI1.3	“Changing the graphics background color.”
	PI1.4	Big Picture Building

between the Portuguese State and the hospitals where the levels of economic and financial assistance that are assured by each hospital are defined). The dashboards are idealized in the light of the guidelines mentioned before at the level of organization and distribution of information, as well as at the choice of graphics and color choices. Its primary objective is to provide ready to use information for decision makers.

Evaluation

After the first presentation/interview, the following feedback was obtained: 3 positive aspects, 2 negative ones and 4 improvement proposals, as shown in Table 9.

The positive aspects are related to the easy analysis and consultation of dashboards due to the way of presenting the information, the choice of graphics also helped make dashboards easy to read. Another point raised is that the dashboards proposed only to present data of the hospital organization which enables a clearer idea and focus of the organization, when compared to the broader scopus of available NHS information. The negative aspects are related to the organization of the information that was not in agreement with the logical distribution of KPIs and with the choice of background colors that sometimes makes it difficult to analyze the graphs’ information. At the level of the improvement proposals these are essentially of the information type, and of visualization. The

valuable feedback on improvements is pertinent for redesigning the panels toward a more user-friendly dashboard.

Second DSR iteration

Improvements

The improvement proposals are presented in Table 10, to enable a synthetic overview. As it is possible to confirm, all the 4 proposed improvements by the interviewees were implemented. The last column, “Figure”, references the affected screens of the dashboard by each implementation. The fact that the initial proposal is aligned with the NHS indicators justified different views of the information to assess the status of the specific hospital. Thus, all improvements were considered important to focus the dashboard on the unit’s productivity.

Demonstration

By comparing both Figs. 3 and 6, it is possible to understand the visual impact of the requested enhancement which was implemented as a result of the new graphic component. The Gestalt closure principle was taken into account to assure a proper separation between the components and KPIs that present the comparison between year N and year N-1 and the component that presents the comparison between the year N and target.

Table 10 Proposed improvements (2nd iteration)

PI	Proposed improvement	Type	Implemented	Who suggested	Figure
PI1.1	Creation of KPIs graph that allows the comparison of the current year with the homologous	Information	Yes	Interviewee	7
PI1.2	Improvement in the organization of the information of KPIs plus macro for the more micro	Information	Yes	Interviewee	6, 7, 8
PI1.3	Changing the graphics background color	Visualization	Yes	Interviewee	6, 7, 8
PI1.4	Big Picture Building	Information	Yes	Author	9

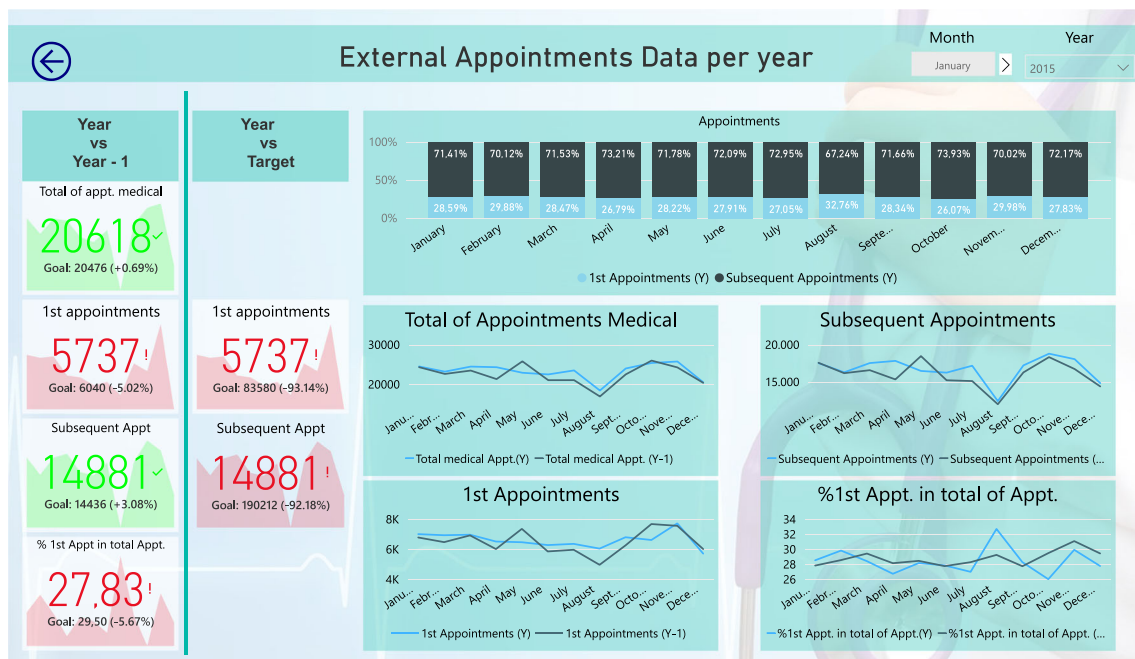


Fig. 6 The monthly perspective of external appointments (2nd iteration)

Additionally, the new graphic component of KPIs that is located on the left side considered the three Gestalt principles of visual perception, specifically: proximity, similarity, and enclosure.

The implementation of PI1.2 deals with the logical reorganization of the information of the KPIs. The new organization aims to make the KPIs more comprehensive. A comparison of Figs. 4 and 7 enables to highlight the differences.

PI1.3 is related to background color adjustments, which affected all the three initially proposed screens of the dashboard. The background color became darker, as a result of tuning the transparency effect. As it can be seen in comparison with Figs. 3, 4, and 5, it did not cause visual loss; on the opposite, this adjustment made it possible to improve the

visualization and increase the focus on the data. It is aligned with good practices, namely rule 2 of the “rules for using color in charts” described in Table 5.

Evaluation

The PI1.4 refers to the Big Picture and it is a suggestion of improvement related to providing a general perspective of the four segments that appear in the panel. The Big Picture contributes for the stakeholders to have a sense of the alignment and commitment that their goals should have for the improvement of the hospital organization [67]. Thus, Fig. 9 presents the first proposal with strategic KPIs per segment.

Fig. 7 The annual perspective of external appointments (2nd iteration)

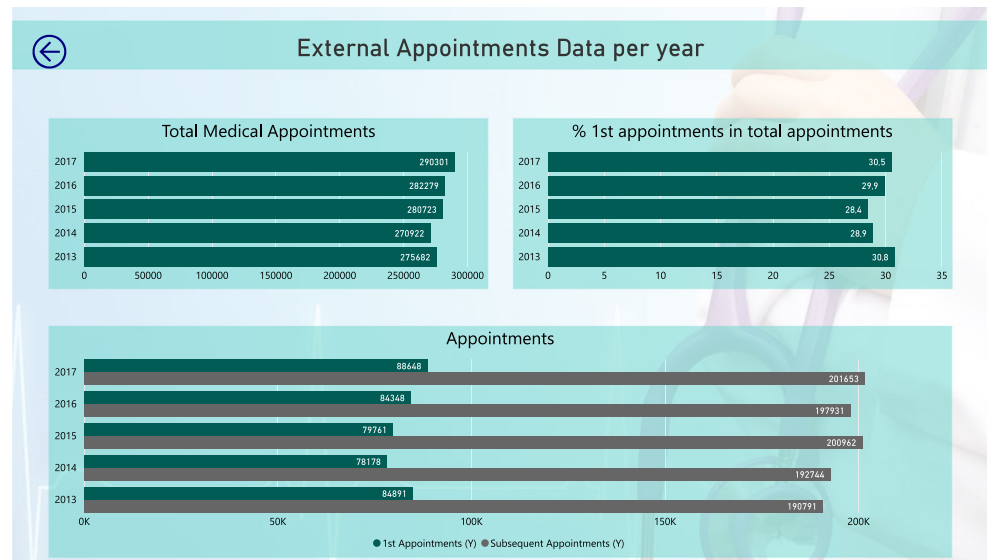
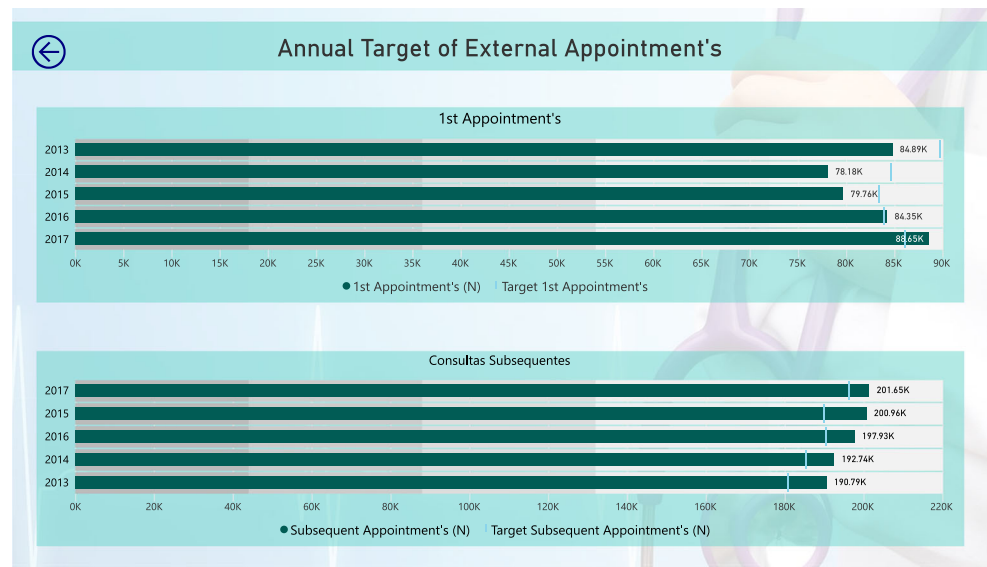


Fig. 8 The Annual Target of External Appointments (2nd iteration)



After the second interview the result was a total of 3 positive aspects, 3 negative aspects and 4 suggestions for improvement, as shown in Table 11. The praised aspects are related to information visualization issues which were considered a plus compared to NHS dashboards. The negative aspects concern to information: the obtained feedback pointed to the lack of a possibility to access to more detailed information (i.e. at the department level, service and health professional), although the macro-information was considered relevant. The macro information presented is important. The interviewees

proposed improvements to meet the above mentioned negative aspects, and also new improvements for more emergency information and navigability improvement.

Third DSR iteration

Improvements

In this iteration, only 2/4 of the suggested improvements were implemented (Table 12). The PI2.1 is interesting and there is

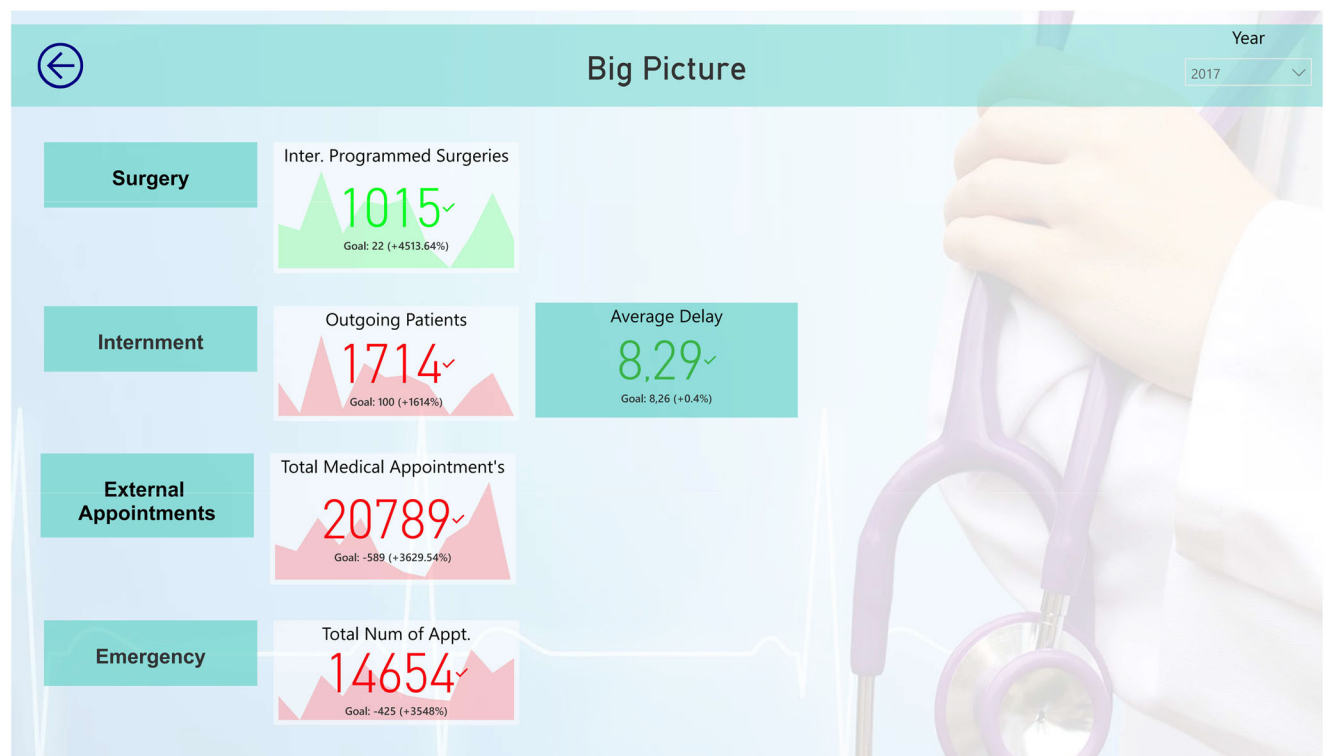


Fig. 9 Big picture (2nd iteration)

Table 11 Evaluation of the prototype (2nd iteration)

	ID	Synthesis
Pros	P2.1	“The dashboard allows immediate analysis and monitoring of production data and hospital productivity”
	P2.2	“Good colour pallet helps with information readings”
	P2.3	“The dashboard displays only hospital information unlike the NHS”
Cons	C2.1	“It is a macro view of production and productivity”
	C2.2	“It was an advantage if the panel allowed for detailed analysis by specialty, services and stakeholders.”
	C2.3	“Lack of emergency target data”
Proposed Improvements	PI2.1	“Obtain data at the contractual level.”
	PI2.2	“Allow for a more detailed analysis of the information, allowing an analysis by specialty, service and health stakeholders.”
	PI2.3	“Add more emergency information.”
	PI2.4	Navigation buttons

already part of the data that appears in the dashboard and that was obtained from the contracts’ program which was used to present the tasks included in the dashboard. Yet, the request is far beyond this information and its implementation would require a thorough query to data in distinct formats including unstructured types, which would demand additional cleaning and preparation. Additionally, the main obstacle to this implementation is the fact that the granularity available at NHS website is lower than the required to meet the interviewees’ requests. Therefore, this is left as future work. Likewise, the implementation of PI2.2 was not possible because the needed data was not available to the public. This lack of information is a limitation to the usefulness of the dashboard, although it should be emphasized the premise that is behind its development: the use of public data.

Demonstration

Suggestion PI2.3 deals with the implementation of the emergency department’s annual objectives. This is a segment that was already in the control panel, but which only needed an additional emergency separator and to take advantage of the graphic components that were already used for other components. Figure 10, shows 4 KPIs with defined objectives, which makes possible to assess if the objectives were reached or not.

The suggestion PI2.4 had the purpose to attribute a significant improvement in the navigability between the monthly

data and annual data as it is possible to see in the blue button in Figs. 12 and 13. This necessity was verified after the first two interviews. It was found that it should be some way of navigating between these two views of the data.

Evaluation

After the third interview, the result was 3 positive aspects, 4 negative aspects and 12 suggestions for improvement (Table 13). The 3 positive aspects are similar to those identified in the previous iteration, showing there is more work needed to tune the dashboard so that the interviewees recognize some of the improvements introduced in the second iteration. Negative aspects are related with issues of obtaining information and presenting non-published information.

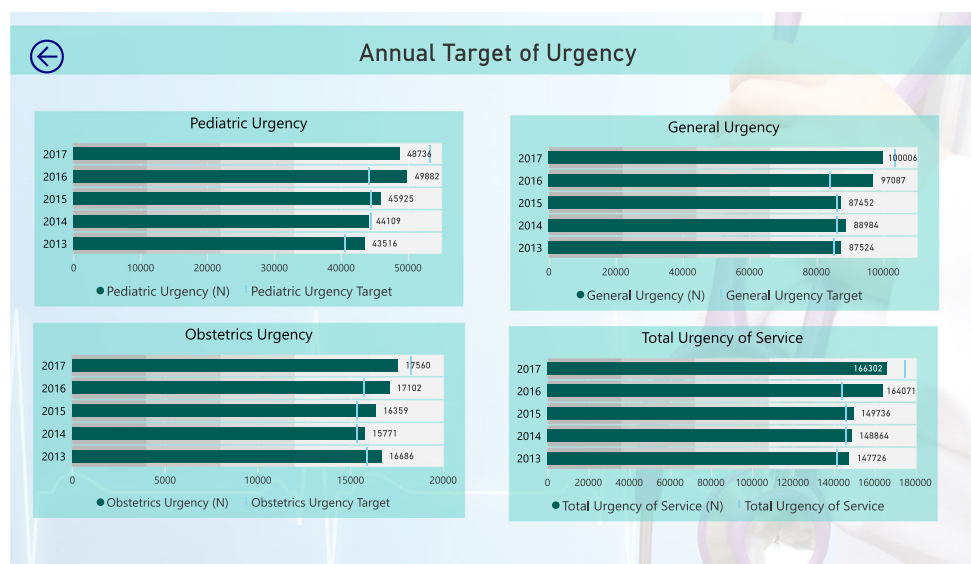
Fourth DSR iteration

Improvements

In this fourth and final iteration, 6 out of the 12 improvements suggested by the interviewees were implemented (Table 14). Proposal PI3.1 is the same as proposal PI2.1 from previous iteration; likewise, the justification for not implementing it is the same. Nevertheless, it further emphasizes the need for a consolidated data mart including not only public data, but also private organizational data under the same dashboard. The

Table 12 Proposed improvements (2nd iteration)

PI	Proposed improvement	Type	Implemented?	Who suggested?	Figure
PI2.1	“Obtain data at the contractual level.”	Information	No	Interviewee	—
PI2.2	“Allow for a more detailed analysis of the information, allowing an analysis by department, service and health stakeholders.”	Visualization	No	Interviewee	—
PI2.3	“Add more emergency information.”	Information	Yes	Interviewee	10
PI2.4	Navigation buttons	Navigation	Yes	Author	11, 12

Fig. 10 The Annual Target of Emergencies (3rd iteration)

suggestion PI3.8 was not implemented due to lack of an adequate data infrastructure that consolidates historical information. Likewise, PI3.9 to PI3.11 were not implemented for the same reasons. These are left for future research under the theme of data quality and data governance. Finally, PI3.12 reflects a much-needed messaging automated service to disseminate the information. Unfortunately, to implement it an integration of the current platform with the public dashboard.

It is interesting to note that the dashboard has evolved to a more mature state up to the point that led the interviewees to come up with new ideas to further improving it, which

resulted in a larger number of improvement items focused on details.

Demonstration

The PI3.2 suggestion aims to improve the navigability of the dashboard. Thus, the authors have implemented links that lead to the main dashboard (the segments have associated links). By looking at Fig. 14, the names of the segments enable loading the corresponding information. PI3.3 deals with the issue of concentrating all information on the left side. As such, the

Table 13 Evaluation of the prototype (3rd iteration)

	ID	Synthesis
Pros	P3.1	"The dashboard allows immediate analysis and monitoring of production data and hospital productivity."
	P3.2	"Good colour pallet helps with information readings."
	P3.3	"The dashboard displays only hospital information unlike the NHS."
Cons	C3.1	"It is a macro view of production and productivity."
	C3.2	"It was a plus if the dashboard allowed for a detailed analysis by department, services and stakeholders."
	C3.3	"Implement information of the day hospital."
Proposed Improvements	PI3.1	"Obtain data at the contractual level."
	PI3.2	"Placing button in the Big Picture to access the Main Panel."
	PI3.3	"Modify the presentation form of Big Picture data."
Proposed Improvements	PI3.4	"Modify the location of the Big Picture button and increase its size to give more prominence."
	PI3.5	"Place links on the label of the segments that lead to the main panel."
	PI3.6	"Change the background of the graphs so that there is a coherence between the segments and information that appears in both the monthly data separator and the annual data also, target."
	PI3.7	"Change the text that appears on the monthly button."
	PI3.8	"Put two years in the Big Picture (Try to put two years in the big picture (2017 and 2018))."
	PI3.9	"Putting all hospitals on the database and filtering information by hospital."
	PI3.10	"Put two hospitals in the big picture."
	PI3.11	"Obtain information using "Relatório Analítico do Desempenho Económico e Financeiro" (RADEF)."
	PI3.12	"Send an MSM to stakeholders with the main data."

Table 14 Proposed improvements (4th iteration)

PI	Proposed improvement	Type	Implemented?	Who Suggested?	Figure
PI3.1	"Obtain data at the contractual level."	Layout	No	Interviewee	–
PI3.2	"Placing Button in the Big Picture to access the Main Panel."	Navigation	Yes	Interviewee	13
PI3.3	"Modify the presentation form of Big Picture data."	Visualization	Yes	Interviewee	13
PI3.4	"Modify the location of the Big Picture button and increase its size to give more prominence."	Visualization	Yes	Interviewee	14
PI3.5	"Put links on the label of the segments that lead to the main panel."	Navigation	Yes	Interviewee	14
PI3.6	"Change the background of the graphs so that there is a coherence between the segments and information that appears in both the monthly data separator and the annual data also, target."	Visualization	Yes	Interviewee	13, 14, 15, 16, 17
PI3.7	"Change the text that appears on the monthly button."	Visualization	Yes	Interviewee	16
PI3.8	"Put two years in the Big Picture (Try to put two years in the big picture (2017 and 2018))."	Visualization	No	Interviewee	–
PI3.9	"Put two hospitals in the big picture."	Visualization	No	Interviewee	–
PI3.10	"Putting all hospitals on the database and filtering information by hospital."	Information	No	Interviewee	–
PI3.11	"Obtain information using RADEF."	Information	No	Interviewee	–
PI3.12	"Send an MSM to stakeholders with the main data."	Information	No	Interviewee	–

improvement was to optimize space usage in the Big Picture screen (see Fig. 9 versus Fig. 13).

The PI3.4 proposal deals with the need to highlight the Big Picture button. According to the interviewees, this is an important feature that requires a place of greater prominence.

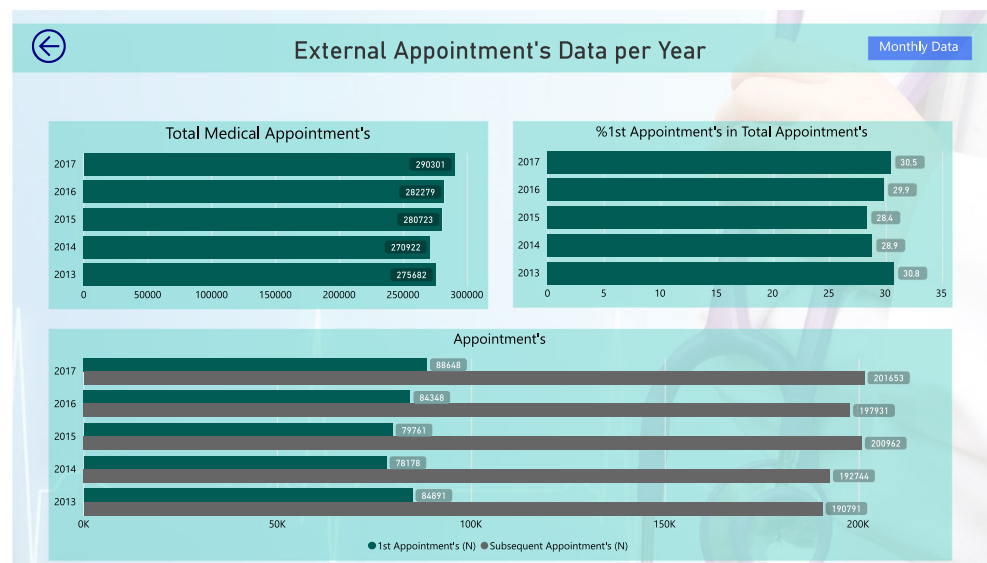
PI3.5 is reinforcing suggestion PI3.2, i.e. by including links in the labels to the segments, as well as other improvements about navigability, as shown in Fig. 13. The proposals identified in PI3.6. have the purpose of defining one color per segment and use that color in the background of all the graphic components of that segment. This change helps to create logical coherence between the graphic components and the segments. This change is based on the first rule in Table 5. This can be seen in Figs. 15, 16, and 17.

Proposal PI3.7 suggested the change of the text of the button that enables access to monthly detail information (it can be seen in Fig. 11 on the upper right corner, labeled "Monthly data", now changed to "Monthly details"). This change allows a better understanding of what the user will get by pressing it.

Evaluation

After the fourth interview, the result was 2 positive aspects, 2 negative aspects and 1 suggestion for improvement, according to Table 15. Again, in the fourth interview, the positive comments are related to data visualization and focus issues that are addressed in the dashboard

Fig. 11 The annual perspective of external appointments (3rd iteration)



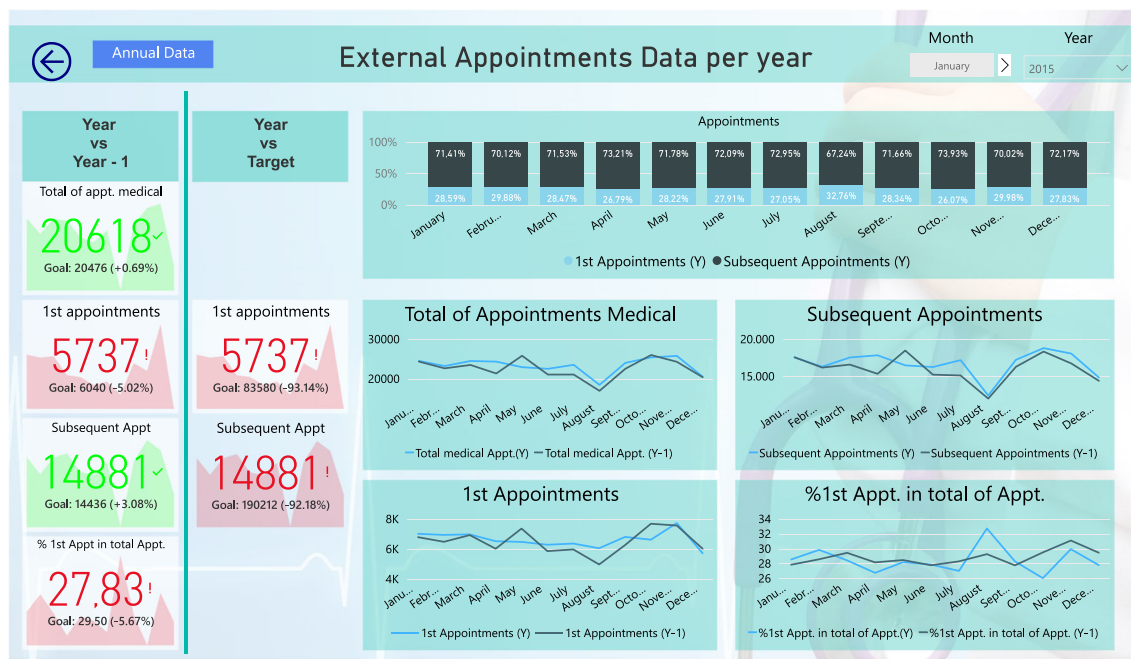


Fig. 12 The annual perspective of external appointments (3rd iteration)

for analysis of just one hospital organization. Negative aspects relate to the lack of more information that makes it impossible to analyze at a finer grain. Likewise, the proposed improvement would require access to private data and to build a data mart encompassing both private (not accessible) and public data.

Conclusion and future work

Contributions

This research contributes in several ways to current state-of-the-art in dashboards applied to health. First, it highlights the relevance of Design Science Research to

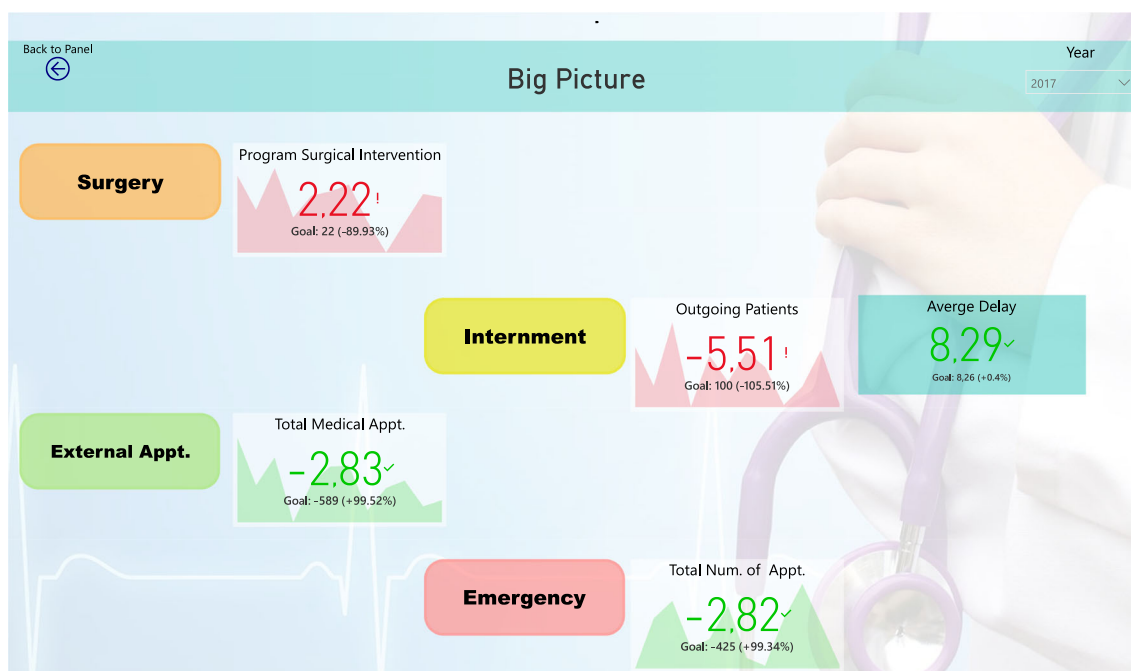
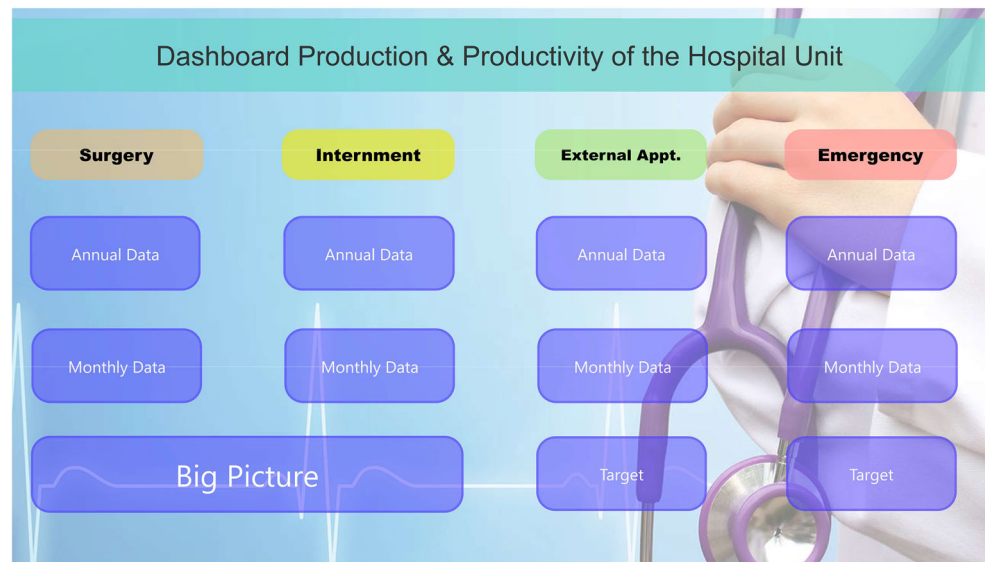


Fig. 13 Big Picture (4th iteration)

Fig. 14 Main panel (4th iteration)



build a decision support tool for health professionals. It does so by methodologically executing a series of cyclic iterations which enabled to tune the dashboard. Second, it shows how public health data can be adopted in a unique tool to focus on a single hospital and bring additional and insightful information that can be easily understood. Finally, by involving relevant stakeholders which, in turn, are also decision makers, the evaluation procedure undertook enabled to assess the dashboard usefulness on real scenario. Thus, the developed dashboard, although requiring further tuning (as highlighted in the following two subsections) helps to fill a gap in

health information based on public data to support decisions in a hospital.

Limitations

The research has some limitations. First, it was performed only in one hospital, which made it difficult to generalize the conclusions, despite interviewees experience. Second, only 4 interviews were made, which means that more improvements can be proposed in the future with more interviews. However, these 4 interviews were made to professionals who need to obtain this type of information (real stakeholders). Third, it

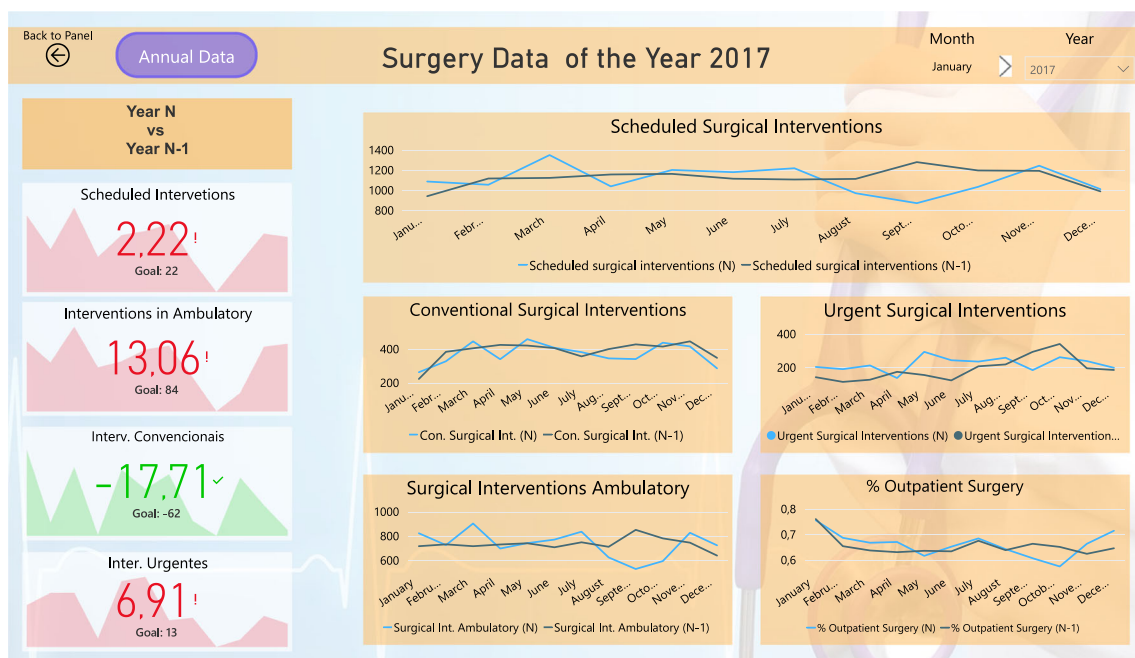
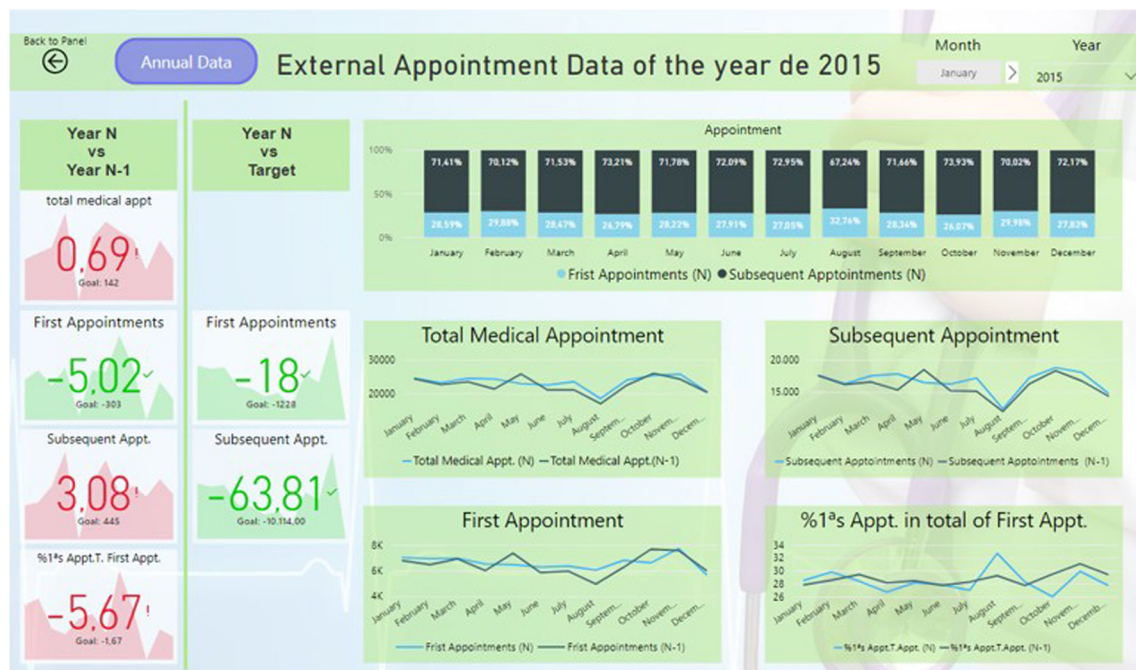
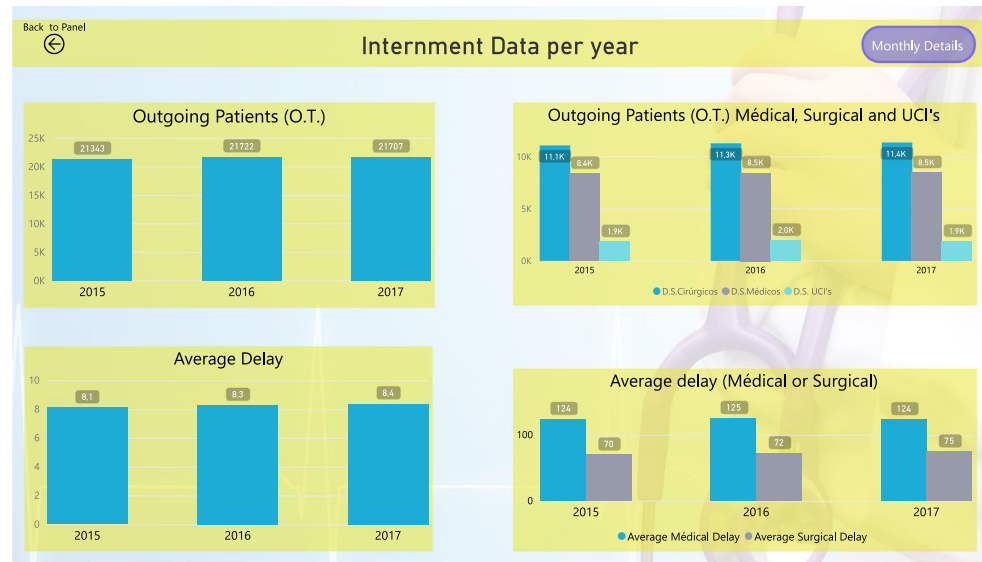


Fig. 15 Surgery data per year (4th iteration)

Fig. 16 Internment data per year (4th iteration)**Fig. 17** External appointment data (4th iteration)**Table 15** Evaluation of the prototype (4th iteration)

	ID	Synthesis
Pros	P4.1	"The fact that it is a dashboard that enables immediate analysis of production information and productivity of the hospital."
	P4.2	"To be a decision support tool focused on a single hospital organization."
Cons	C4.1	"It is a macro view of production and productivity"
	C4.2	"The Dashboard should have information that would allow analysis at the departmental, service and stakeholder levels."
Proposed Improvements	PI4.1	"Obtain data at the contractual level."

was not possible to implement all the improvements proposed due to the need to access private data, although some of the proposals are already registered for future development.

Future work

As a proposal for future work, it was very interesting to continue the research with more iterations in the same hospital and other hospitals. This will allow, on the one hand, to create a more complete dashboard and the possibility of obtaining conclusions that allow the generalization and consequent implementation of the dashboard in other hospital organizations. Another proposal for future work is to gain access to private data from hospitals and thus be able to present more information than just the public information.

Compliance with ethical standards

Conflict of interest The authors declare that they do not have conflicts of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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