KTH Computer Science
and Communication

Real-time Benchmarking with a Business Intelligence System

A Case Study of Aravind Eye Care System

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The International Relations Office at KTH the Royal Institute of Technology, Stockholm, Sweden, administers the MFS Programme within engineering and applied natural sciences.

Erika Svensson
Programme Officer
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Abstract

39 million people in the world are blind and approximately 15 million of them live in India. Aravind Eye Care System is the biggest provider of eye care in India and the world and it continues to expand and spread medical understanding and best practice to improve ophthalmological care.

Aravind Hospitals measure data of performance indicators for management and identify best practice. Currently, each department handles data of these parameters in locally stored excel sheets which limiting benchmarking in real-time. The main objective of this project has been to develop a user-friendly web platform that enables real time benchmarking across all of Aravind's hospitals.

A prototype of a web based business intelligence system has been developed as a proof of concept. The aim of this prototype has been to enable benchmarking across Aravind's hospitals. The impact has been studied to analyse the extents to which the organization can become more efficient through continuous benchmarking. Initially, a database was developed containing data from the glaucoma clinics in Coimbatore, Madurai, Pondicherry and Tirunelveli. Subsequent was a web platform developed which presents the data dynamically with Google Charts.

Interviews and analyses support the implementation of a business intelligence system at Aravind's Hospitals. Testing and analysis have proven that a business intelligence system can improve value, create innovation and spread best practice at Aravind's Hospitals.

Keywords: Benchmarking, Business Intelligence System (BI), Health ICT, MFS

Referat

39 miljoner personer i världen är blinda och uppskattningsvis 15 miljoner av dem bor i Indien. Aravind Eye Care System är de största leverantörerna av ögonsjukvård i Indien och i världen. De fortsätter växa och sprida medicinsk kunskap och best practice för att förbättra ögonsjukvården.

Aravinds sjukhus mäter data på nyckelparametrar av verksamheten för management och för att identifiera best practice. För närvarande så hanterar varje avdelning data av dessa parametrar i lokalt lagrade Excel dokument vilket begränsar benchmarking i realtid. Det huvudsakliga syftet med detta projekt har varit att utveckla en användarvänlig web plattform som möjliggör benchmarking mellan Aravinds sjukhus i realtid.

En prototyp av ett web baserat business intelligence system har utvecklats i form av ett proof of concept. Syftet med denna prototyp har varit att möjliggöra benchmarking mellan Aravinds sjukhus. Dess påverkan har utvärderats och analyserats för att studera till vilken utsträckning organisationen kan bli mer effektiv genom kontinuerlig benchmarking. Till en början har en databas utvecklats för att hantera data från glaukom klinikerna i Coimbatore, Madurai, Pondicherry and Tirunelveli. Där efter har en web plattform utvecklats som presenterar dynamisk data med Google Charts.

Intervjuer och analyser stödjer implementationen av ett business intelligence system på Aravinds sjukhus. Denna rapport har bevisat att det är genomförbart att utveckla en skalbar open-source webbplattform som möjliggör benchmarking i realtid. Tester och analyser har även visat att ett business intelligence kan vara värdeskapande, innovation skapande samt sprida kunskap på Aravinds sjukhus.

Acknowledgements

I am heartily thankful to Aravind Eye Care System for giving the time and possibility of this study. Great thanks are specially dedicated to Mr C.Gnanasekaran who supervised this project and dedicated time and shared knowledge. I also like to thank every participant at Aravind who contribute with time and inspiration. I would also like to thank SIDA and the MFS committee at KTH who granted me the MFS scholarship. Special thanks goes to my supervisor and examiner, Alexander Baltatzis, at the school of computer science and communication at KTH who supported me through this project.

Contents

Chapter 1

Introduction

The first chapter of this document provides an introduction to this case study and the topics that are to be dealt with throughout the present research work. First, the background of the project is discussed, leading to the formulation of the problem that will be addressed, along with the proposed research questions that will be answered in the end of this study. This is followed by the scope that will be covered and the contributions the author wants to make by the end of the project.

1.1 Background

1.1.1 Aravind Eye Care System

In 1976 Dr. G. Venkataswamy known as Dr. V. founded Aravind Eye Hospital with the vision to help the poor blind people in southern India by providing quality eye care at a reasonable cost. At that time the private clinic only had eleven beds and was located in his brothers home in Madurai. Today, Aravind Eye Care System is the largest provider of eye care in the world and still share Dr. V vision to eliminate needless blindness.

The World Health Organization, WHO, emphasize in there action plan 2014-2019 the opportunity to change millions of peoples lives with an eye operation. In 2010 they estimated that there were 285 million people in the world who were visually impaired, of which 39 million were blind and 15 million of those lived in India. Two thirds of the visually impaired people could recover good sight by cataract surgery [WHO, 2013]. Aravind Eye Hospitals performed 241,440 cataract surgeries in the year 2013 [Aravind 2014] of which half of the patients were non-paying or very subsidized and the other half were paying [Aravind, 2014]. This is achievable through high quality and productivity in a well-organized system with streamlined patient flow.

Aravind Eye Care System is a network of ophthalmologic hospitals and is built upon five tertiary eye care centres in southern India. These centres provide speciality care, research and training. The network also has five secondary eye-care centres which perform cataract service and speciality diagnosis. Aravind also make eye examination and treatment of minor ailments on there six outpatient centres. Aravinds 46 primary centres perform eye examination and are typically run by two nurses. R. Carter Clement explains this as a hub-and-spoke model were the tertiary eye care centre works like a hub, the secondary hospitals as spokes and the primary centres refer patients to the tertiary eye care centres [Burns, 2014].

Cataract is the main cause of blindness and the majority is age-related. In a cataract eye the lens becomes clouded and light is not easily transmitted to the retina. This is treated with a fairly standardized operation were the clouded lens is removed and replaced with glass lens know as an intraocular lens (IOL). At the time when Aravind Eye Hospital was founded, IOLs were imported from the United States and were relatively expensive. In order to expand the business Aravind had to invent a way to reduce the cost of IOLs. Aurolab was established in 1992 as a non-profit charitable trust with the mission of making high quality ophthalmic products, affordable and accessible to vision impaired worldwide. Thereby they were able to reduce the price of IOLs from approximately $30 to $2 apiece [Ragan, 1993]. Today, Aurolab manufactures ophthalmic supplies, which are exported to more than 130 countries worldwide.

1.1.2 Management with the Aravind Model

Aravind Eye Hospital is constantly growing with a mentality that *"if you're not growing, you're shrinking"*. In this expansion mode one key issue is monitoring each hospital by measuring specific parameters. This process is fairly streamlined and well defined. The human resource department in Madurai together with the clinical heads and the chief medical officer, CMO, evaluate all the hospitals quarterly. These parameters and evaluations have been proven to be invaluable for the organization. The parameters measure both values which are directly business related e.g. numbers of patients, cost per patient, complication after surgery etc. and also soft values such as participation in workshops and curricular activities, number of meetings etc.

In an interview with Dr V. in a case study from Harvard in 1993 Dr V. tries to explains his vision and business model as a similarity between hamburgers and eye care:

> *"Tell me, can cataract surgery be marketed like hamburgers? Don't you call it social marketing or something? See, in America, McDonald's*

> *and Dunkin' Donuts and Pizza Hut have all mastered the art of mass marketing. We have to do something like that to clear the backlog of 20 million blind eyes in India. We perform only one million cataract surgeries a year. At this rate we cannot catch up. - Dr V."* [Ragan, 1993]

Aravind is continuously promoting best practice and in 2013 it was rewarded with a grant from the Hilton Foundation and Bloomberg Philanthropies that will take an entrepreneurial approach and support five ophthalmologists in Ethiopia, Zambia, Nigeria and Kenya and provide guidance of strategic planning, training, on-site support and putting in IT-systems. One of Aravinds ways of reaching out and spread best practise to eye hospitals beyond Aravind is by their international training facility for eye care; Lions Aravind Institute of Community Ophthalmology (LAICO). In many cases of eye care the problem is not relating to ophthalmology but the lack of environment, creating the demand, lack of good supply chain, policies and procedures that could be addressed by good programme design and efficient management [Burns, 2014].

1.2 Problem Definition

Aravind store and administer hospital parameters in different data systems. In order to evaluate each clinic, data must be pulled from these systems. That data are then controlled and compiled into Excel-sheets thereby can benchmarking across the hospitals be achieved. The results are analysed and summarized in reports, which are mailed to the corresponding department. Since this is a time-consuming procedure there are no possibilities to do these comparative evaluations on a monthly or weekly period. This creates a lack of insight in the daily business for all the employees as well as for the board. Furthermore, detecting improvement and declines across the departments in real time is difficult. Hence, it is also impossible to take urgent preventative decisions or spread best practice in the time needed.

This case study has focused on to solve the problem of locally stored and handled performance indicators through developing a prototype of a business intelligence system that can present real-time benchmarking for Aravind's hospitals. Further, this prototype has been evaluated in order to answer the question if this tool can improve the organization.

1.3 Scope

Aravind Eye Hospital is market leader and a role model in medical eye care, especially in developing countries. External benchmarking and identification of best

practise could spread fast to hospitals beyond Aravind. Hence, development of information and communications technology (ICT) at Aravind can hypothetically accelerate medical outcomes globally. Previous studies on information technology (IT) in health care have shown that IT is becoming a critical resource for enabling quality and efficiency in patient care [Finkelstein et al., 2012]. This paper aims to investigate the extents to which ICT in form of a business intelligence system can affect the management of Aravind Eye Care System.

This project has been designed as a proof of concept and developed with a user-centered approach. Limitation has been set to the glaucoma clinics in the four tertiary hospitals in Coimbatore, Madurai, Tirunelveli and Pondicherry. This limitation has been set due to the time limit of this study and since these four tertiary hospitals share great similarities of parameters.

Chapter 2

Theory

In this chapter is the theoretical framework described. It focuses is on how to design interactive systems, prototypes and what to think about when displaying data in an interactive system.

2.1 Designing interactive systems

In the past, system development has tended towards being ”technology-centered”. Today developers aim to develop systems that are accessible and pleasant to use rather than focusing on the technology itself [Benyon, 2010]. Interactive systems are commonly developed today. David Benyon describes these as; *”Interactive systems are things that deal with the transmission, display, storage or transformation of information that people can perceive. They are devices and systems that respond dynamically to people's actions.”* [Benyon, 2010]. He also states that a big challenge when designing interactive systems are the fundamental fact that people interact with systems in a different way. Therefore, a developer needs to involve and understand the user. Benyon (2010) means that the interactive systems design approach contains four major processes, which are described in figure 2.1.

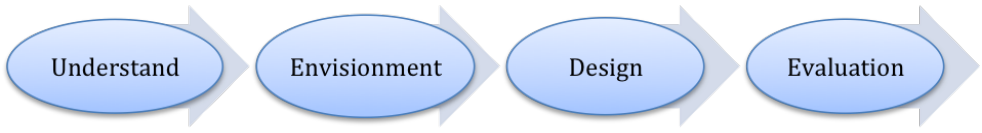

Figure 2.1. Design approach

On the same way have a broad study of development of health ICT in developing countries concluded that the technology should be:

- Kept simple, relevant and local
- Built on existing systems

- Involve users in the design
- Include communication strategies in the design of ICT projects
- Introduce greater monitoring and evaluation, particularly participatory approaches

[Chetley, 2006].

2.2 Prototypes

Prototypes are great communication tools and also good for outstanding means of receiving opinions about certain design implementation. Prototypes are often used to display a concept but can also be used to show functionality. Still the main distinguished characteristic of a prototype is that it is interactive [Benyon, 2010]. However, that does not mean a prototype needs to be a fully functional software, it can be interactive by a person switching Post-its. Youn-Kyung Lim state that *"Prototypes stimulate reflections, and designers use them to frame, refine, and discover possibilities in a design space"* [Lim et al., 2008].
High fidelity, HI-FI, prototypes are similar to the final product, as far as the user sees it. The functionality is not necessarily the same as the end product but it gives a reflection of how the final product will function. According to Benyon (2010) are HI-FI prototypes suitable for detailed evaluation of main elements such as content, visuals, interactivity and functionality. He also clarifies that HI-FI prototypes can be used for studies to determine if people can learn to use the system.

2.3 Information presentation framework

This paragraph presents guidelines and important aspects to think about when presenting information in an interactive system. All interactive systems have some information to be presented to the user, one way or the other. According to Summerville (2007) it is an advantage for the developer and a good guideline to separate the information e.g. a database, from the software that is required to present the information. That way can the information be updated with out changing the software and vice versa. Model view control, MVC, is another approach of presenting the data. The approach supports multiple presentations of data and lets the user interact with the system by input devices such as mouse or keyboard. The MVC-approach let the user interact with the information in a way that is appropriate to the specific situation. For example, a model that represents a numeric value e.g. number of patients might be represented by both a view with a pie chart and a view of a table.

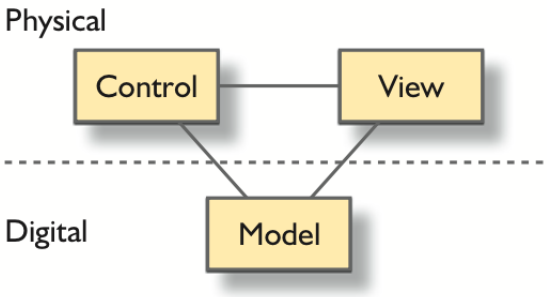

Figure 2.2. MVC, Benyon, 2010

2.4 Benchmarking

Benchmarking is a process of comparison between the performance characteristics of separate, often competing, organizations intended to enable each participant to improve its own performance in the marketplace. The objectives are to obtain a clearer understanding of competitors success factor and of customers' requirements. Benchmarking will also enable innovations (either of processes or products) to spread more rapidly through an industry [Beckford, 1998].

Literature of benchmarking is mainly separated into two parts: internal and external benchmarking [Camp, 1998]. Internal benchmarking covers two-way communication and sharing opinions between departments within the same organisation or between organisations operating as part of a chain in different countries. Once any part of an organisation has a better performance indicator, others can learn how this was achieved. Findings of internal benchmarking can then be used as a baseline for extending benchmarking to include external organisations [McNair and Leibfried, 1992]. This report has mainly focused on internal benchmarking within the departments of Aravind's hospitals. Still the interest and benefits of external benchmarking will be addressed in the discussion.

2.5 Present the information

Due to the limited screen space is it important to present information in the right manner. Different persons may need different data. Therefore is it important for the developer to know how the information will be extracted and why. If the user is interested in the relationships between data rather than a specific value, then a graphic representation should be picked [Sommerville, 2007]. Different charts have different advantages; trends are easily distinguished from line charts. This can be useful for an executive manager who are not interested in the exact numbers but

like a quick overview of the growth. Another way of presenting data in a graphical view is by comparison to a fixed value or goal, which can be displayed on a scale.

Chapter 3

Method

This section describes the work that has been carried out in order to complete this study. The work process has followed the design approach presented in the previous chapter. A user-friendly web platform has been developed on an elastic compute cloud and the dynamic data are presented in an interactive way. Evaluations of the product have primarily been done with interviews and meetings.

3.1 Pre-study of Aravind Eye Hospital, Madurai

In order to get a deeper understanding of the parameters and how they would be implemented into a web-platform, the patient flow and the computer systems was studied on a guided tour at the main hospital in Madurai with Mr C.Gnanasekaran. This was followed by analysing the existing Excel-sheets containing the data of the parameters. Each hospital had some variety of the parameters, because of this a template sheet was created including the varieties without abundance. This was done in collaboration with Mr C.Gnanasekaran. The board and head physicians approved the template to ensure that it was correct.

3.2 Envisionment

After the pre-study and when a basic understanding of the parameters was achieved, it was time to visualize and externalize the ideas into something that the users could perceive. According to Benyon (2010) is envisionment a process to bring abstract ideas to life. This can take form in different shapes e.g. requirements, scenarios, mind-maps, sketches and snapshots or software prototypes.

During the understanding phase a lot of information was gained about which employees who would use the platform and what information they wanted to extract. On this basis were scenarios created. The ide of conceptual scenarios was to reveal details about the employees' thoughts about the product and their requirements.

Three example scenarios:

A manager would like to compare the ratio of free, paying or patient coming from camps between four hospitals. He would also like to know the number of out patients of each hospital.

A doctor would like to know if any investigation method has been used more frequently during the last year.

A HR manager would like to know if the number of employees are higher the usual.

On a wall a mind-map was created with Post-its, it helped to organize the parameters of the different hospitals and to summarize the ideas of a design. This lead to paper sketches of a web design. The main idea of these sketches was to capture the initial inspiration and ideas. From the scenarios and paper sketches was a HI-FI prototype developed in form of a website without a backend. Google Charts graphs were coded with sample data so they still would be interactive. This "shell" was used to get feedback from users. The HI-FI prototype was refined in the design process.

3.3 Design

Benyon (2010) is dividing the design process into two phases, conceptual and physical design. Conceptual design is basically the logic, functions and structure while the physical design is concerned with the allocation of function between people and artefacts and how the artefact will look and behave.

3.3.1 Server setup

The web platform was developed under the criteria to support expansion and build on open source. Still, the hardware was the only factor that needed to be cost related. The server was setup on an elastic compute cloud (EC2) at Amazon to support web-scalability. Basic server installation with Ubuntu, Apache, MySQL and PHP was executed. Security setting was initialised and enable RSA encrypted SSH connection and only HTTP requests from specific IP-address to minimize the chance of unauthorized requests.

3.3.2 Technical Environment

To enable fast software development the environment was a critical issue. Lots of code has been written during this project and a lot of changes have been made. These updates have been made through SFTP (Secure File Transfer Protocol) to the server. To speed up this process, Cyberduck was used which is an open source client software that enables a connection to a server with an easy interface. Files

can also easily be edited with Sublime Text 2. The database was on the other hand developed through the terminal running MySQL.

3.3.3 Backend

A MySQL database was created to store the information of the parameters described in result section 4.1.1, additional tables were created to support the information of the hospitals.

PHP: Hypertext Preprocessor, is a server-side scripting language, which is a powerful tool for making dynamic and interactive web pages. PHP scripts were written to enable connections to the database and to run SQL queries.

JSON, JavaScript Object Notation, is an open standard format for storing and exchanging data, primarily between a server and a web application. Its format consists of pairs of attributes and values, which are readable without programing knowledge. JSON is an alternative to XML formatted data.

3.3.4 Frontend

The platform had to be user-friendly so employees could and would use it at regular intervals and get information quickly. Bootstrap was implemented to achieve a responsive user-friendly interface. Bootstrap is an open source framework and contains CSS and JavaScript files and components that gives the programmer rich responsive design and tools without limiting the flexibility. Additionally the jQuery library was implemented to enable certain graphic visualisations.

The data is presented with graphical chars enabled though API's from Google Charts. Google Chart is open API's and creates interactive visualisations of JSON-formatted data.

3.4 Evaluation, Interviews and Meetings

In order to evaluate to what extents this prototype can improve benchmarking across Aravinds hospitals, interviews were conducted with doctors and directors. Questions were held open to enhance accurate opinions. The main objective for these interviews was to investigate the doctor's opinion of the current evaluation approach and also to identify the most common inadequacies. The interviews also aimed to identify parameters of greater value for specific department. Additionally weekly meetings were hold with the local supervisor of this study, C.Gnanasekaran, to gain deeper knowledge on how the platform would be implemented.

Chapter 4

Result

This chapter presents the results first from the initial study of the organization. This is followed by a description of the parameter used in the original Excel-sheets used for benchmarking. In a subsequent section is the result from the web development presented in two subsections *backend* and *frontend*. The prototype of the website is presented with a descriptive text and print screens. Last, the results from the interviews are presented.

4.1 Pre study results

This section covers the information gained from the pre study of Aravind's hospital in Madurai. The hospital is divided into a free division and a paying one. The free division serve both direct walk-in patients and also patients who have already been screened on eye camps, which are temporary outreach camps in surrounding villages. The purpose of eye camps is to examine poor people who are not capable to go to the cities and also for marketing and create propaganda to reach more people [Ragan, 1993]. All the people in need of surgery or further investigation are transported with busses to the hospitals without charge. Aravind apply this concept on all tertiary hospitals.

Direct walk in patients on either the paying or free division are entered into the IHMS (Integrated Hospital Management System) and given a case record with unique identification number. Patients from camps will already be registered.

4.1.1 Parameter Report

The parameters are summarized in Excel sheets were some data can be pulled from the IHMS or the CMS (Clinical Management System) while some data has to be entered manually. Measurement of patient data is categorized under paying, free

or camp division. The parameters of the glaucoma clinics are grouped into nine different categories:

- Case Records
- Service
- Investigation
- Surgeries
- Follow up
- Cost
- Human Resources
- Activities
- Meeting

Case Records

The quality of case records are randomly audited and marked on ten criteria's. Normally 2-5 % of the total case records are checked.

1. Patients complaints related to glaucoma
2. Family history of glaucoma
3. Tonometry reading
4. Gonio
5. Fundus cup disc ratio
6. Fields
7. Investigations relating to glaucoma
8. Details regarding medical, surgical or laser treatment
9. Counseling and follow-up
10. Legibility of writing and signature of the doctor.

Service

The patient flow is measured and categorized on the clinic as new patient or a review. Patients who are referred to the glaucoma clinic suspected with glaucoma but proven to be not glaucoma are categorized as cross-references. The service parameter has an error in the classification if the patient is new or a review because the physical case records is only saved for two years. Patients who do not remember their unique identification number will be treated as a new patient.

Investigation

There are various methods to determine if a patient is suffering of glaucoma, but the most common are HFA in combination with Fundus Photo. HFA is basically a way to determine the visual field. OCT, GDX, HRT and CCT are other investigation methods. The frequency of each investigation methods is measured.

Surgeries

Surgeries are divided into sub categories; surgeries, minor procedures, re-surgeries, laser treatment, procedures and complications.

Surgeries	Minor Procedures	Re Surgeries
Combined surgery	DLCPC	AC reformation and Re Suturing
Trabeculectomy	Examination under GA	Cortex Wash / Redialling
DLCP	Bleb Needling	CD drainage
AADI		AGV / AADI Resurgeries

Table 4.1. Surgery Indicators 2

Laser Treatment	Procedures	Complications
YACPI	Bleb revision	Intra Operative Complications
-	Repeat Trab	Surgical Infections
-	-	Bleb failure
-	-	Bleb leak
-	-	Presistant Choridate Detach
-	-	PresistantShallow chamber

Table 4.2. Surgery Indicators 2

Follow-up

The follow-up rate is the percentage of patients who came for follow-up on the same date as advised. It is an important value for the organization in order for better planning in the outpatient department. It is categorized for post surgery and primary follow-up.

Cost

The unit cost is the total annual expenditure of medical equipment and medicine for both the paying and free division.

Human Resources

The parameter of human resources, measure the current manpower and is compared to the standard number. The manpower is categorized under seven groups: medical officers, fellows, Mid Level Ophthalmic Personnel (MLOP) employees, MLOP trainees, counsellor employees, ophthalmology technician and admin.

Activities

Activities are grouped into academic and welfare and are measured in the number of participation.

Meetings

Meetings are given values regular or irregular.

4.2 The Web Platform

This section provides the A prototype of a website have been developed as a proof of concept with three parameters from the glaucoma clinic (service, human resources and investigation). The database contains tables of these parameters and information of hospitals and clinics.

4.2.1 Backend

Each clinic was given a clinic ID that was organized after paying, free or camp, location and speciality. Data was entered from the 2014 parameter report. For example have the free glaucoma clinic in Madurai the clinic ID 20110.

Speciality	PayCampFree	Hospital	ClinicID
Glaucoma	Pay	Madurai	20110
Glaucoma	Pay	Coimbatore	20120
Glaucoma	Pay	Pondicherry	20130
Glaucoma	Pay	Tirunelveli	20140
Glaucoma	Camp	Madurai	20210
Glaucoma	Camp	Coimbatore	20220
Glaucoma	Camp	Pondicherry	20230
Glaucoma	Camp	Tirunelveli	20240
Glaucoma	Free	Madurai	20310
Glaucoma	Free	Coimbatore	20320
Glaucoma	Free	Pondicherry	20330
Glaucoma	Free	Tirunelveli	20340

Figure 4.1. Table of Glaucoma Clinics

The objective for the PHP scripts was to pull data from the database and return it as a JSON string. It uses variables to select the right data from the database. The variables are:
$p = parameter
$h = hospital
$sp = start period
$ep = end period

In appendix A, is an example of a PHP script that pulls data from the service table utilizing the SQL query stated below. The result from this PHP script is a JSON string. An example of this JSON string with the variables; new out patient, Madurai, January and February is presented below the SQL query.

SQL query:

```
SELECT PayCampFree, SUM('.$p.') AS '.$p.'
FROM Service
Join Clinic
on Service.ClinicID = Clinic.ClinicID
WHERE Hospital="'.$h.'" and
StartPeriod ="'.$sp.'" and
EndPeriod = "'.$ep.'"
GROUP BY PayCampFree
```

JSON string:

```
{"cols":[{"label":"PayCampFree","type":"string"},
{"label":"OP_New","type":"number"}],
"rows":[{"c":[{"v":"Camp"},{"v":1345}]},
{"c":[{"v":"Free"},{"v":3574}]},
{"c":[{"v":"Pay"},{"v":10154}]}]}
```

4.2.2 Frontend

Variables described above are chosen from either buttons or from dropdown menus and posted with an AJAX (Asynchronous JavaScript and XML) request to the PHP script in the backend. This enables an exchange of specific data from the SQL queries to be presented in corresponding graphs without updating the whole page. An example of how this is utilized to draw a Pie Chart is described in appendix B.

4.2.3 Design

The four pictures below shows an example of the website from the service, human resource and investigation parameters of the glaucoma clinic. The service parameter is represented in Figure 4.2 and 4.3. These shows the percentage of new outpatient

who are either paying, free and camp, which is represented in the pie charts. The hospitals selected are Madurai and Pondicherry.

Figure 4.3 is the same page as 4.2 after scrolling down and shows the total number of out patient per hospital. This is visualized in a column chart and the raw data are described in a table.

The manpower of human resources is compared in grouped column charts as shown in figure 4.4. The current value is compared with the standard value in order to detect overstaff.

Figure 4.5 represents the investigations methods in line charts. This visualizes how different investigation methods evolve with time. The selected values are the investigation method GDX, both paying, free and camp and the hospital in Madurai from January 2012 to December 2013.

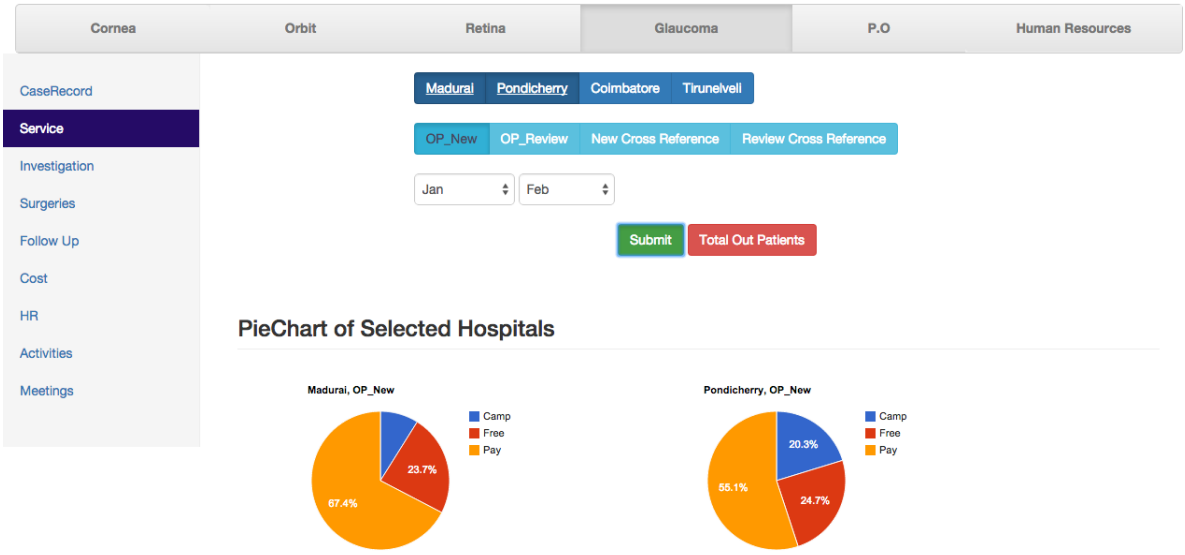

Figure 4.2. Service, percentage of New Out Patients

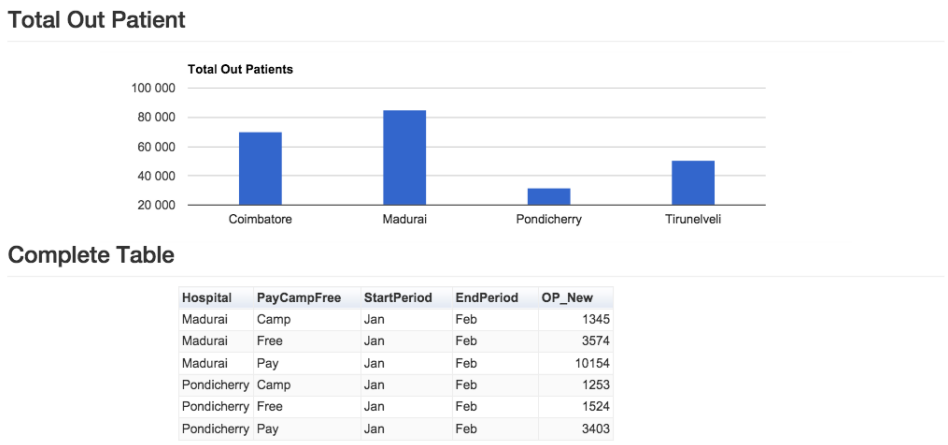

Figure 4.3. Service, Total OutPatients

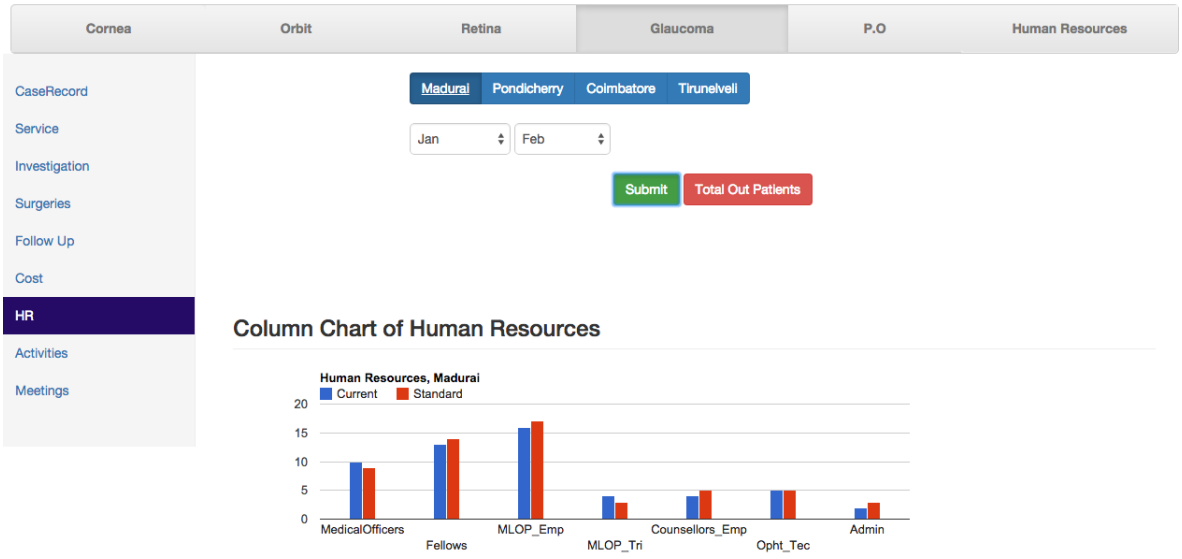

Figure 4.4. Human Resources, column chart of manpower

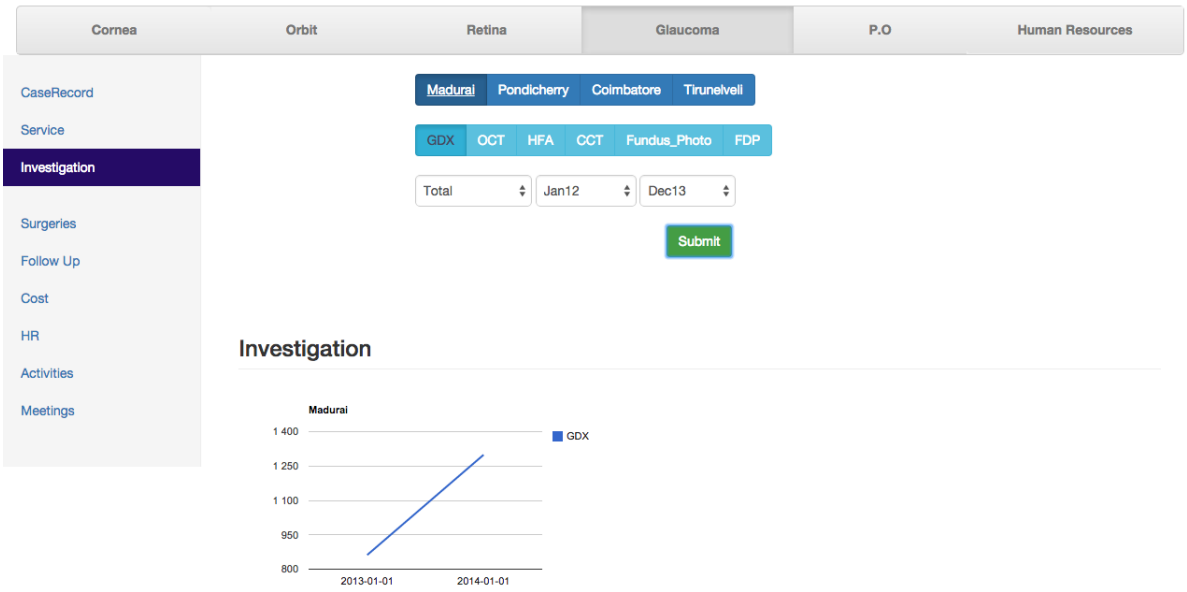

Figure 4.5. Investigations, Number of GDX

4.3 Post Study Results

This section presents the information gathered from the interviews and meetings. These results have been a basis for the evaluation of this study and will be discussed and analysed in chapter five.

Interviews with doctor Krishnadas clarified how the existing benchmarking though excels sheets gives confidence and direction to the organization. He explained how it helps to monitor each unit efficiently and understand the performance, growth, strengths and weaknesses of the individual staff, departments, hospital and the entire organization. The outcome is sharing of best practice and experience and it also creates the opportunity for new innovative methods, ideas and tools to improve their effectiveness.

Interviews with three different employees (Mr C.Gnanasekaran, Doctor Krishnadas and Mr R.D. Thulasiraj) showed different opinions of the web platform. Mr C.Gnanasekaran claimed in an interview that the set of data displayed in the web platform could be used to analyse the business from a macro level. However doctors and managers actually seek to do investigations on a micro level in order to obtain information on specific doctors.

Doctor Krishnadas clarified that during the parameter evaluations and discussion, the teams do not prefer comparison of parameters instead they do deeper analyse of each hospital. He also said that the data is of the biggest interest and not figures. On the other hand, a meeting with Mr. R.D. Thulasiraj emphasized that the benchmarking needs a comparison against the industrial average and the best hospital.

Dr Krishnadas also claimed that one of the most important values for the glaucoma clinic is the number of patients who turn up on review. Likewise he stressed the importance of evaluation meetings in order to spread best practice. Meetings and workshops are the time when departments push themselves to investigate areas of improvement and decline. He estimated that doctors would use a business intelligence system for 30 minutes in a weekly period and for two hours while preparing monthly reports.

Chapter 5

Discussion and Analysis

This chapter discus the results from the previous chapter, and analysis how well the developed system can improve the organization. Furthermore, is a discussion held on ICT in health care followed by evaluation of benchmarking in health care.

An initial objective of the project was to develop a business intelligence system that would serve as a benchmarking tool across Aravind's hospitals. The system developed has enhanced usability and accessibility for comparative measurement of data parameters. According to Cindi Howson, a successful business intelligence system should allow people at all levels of an organization to access, interact with, and analyze data to manage the business, improve performance, discover opportunities and operate efficiently [Howson, 2008]. One of the features with Google chart is that percentage are labelled in the pie chart, but the exact number can de detected by hovering over the corresponding area. This feature is available for all the different charts. Additionally options can also be made such as colour, title, size etc.

The implementation of the developed prototype has been tested and evaluated. Aravind has taken well to the implementation on the four tertiary hospitals because they have fairly streamlined and well-defined parameters. However, some small deviations of parameters make direct comparison of data incorrect e.g. investigations methods of glaucoma depend of the medical equipment. Parameters depending on other data require deeper analysis and the correlation needs to be investigated. Only then can the output of benchmarking result in fundamental decisions that can improve the business. Still, local analyses are possible and can be used for valuable evaluations.

Moreover, interoperability is one issue Aravind needs to investigate further to better obtain raw data from the existing data systems i.e. IHMS and CMS. This is because some data have dual sources and the quality can vary between those and therefore require a manual quality check. According to Kjeld Engel's report on standards for enabling health information interoperability, the healthcare sectors have a lack

of general adaption of industry standard which creates a technological barrier for implementing healthcare-related information technology [Engel et al., 2006]. The positive aspect about the developed system in this study is that data can be pulled from all any SQL database and the backend can be modified without changing the view controller.

5.1 Future fulfilled implementation

This study has been carried out as a proof-of concept with specific parameters on the glaucoma clinic. The report has also investigated the directions for a complete implementation of a business intelligence system on Aravind Eye Hospitals. The developed platform has been proven feasible on the organization and the studied data has also been proven to be suitable for benchmarking.

Aravind's departments are divided into the following: Cataract, Cornea, Glaucoma, Orbit, Paediatric Ophthalmology and Retina. A complete implementation on all departments requires explicit definition of each parameter and precise definition on how the comparison will be done. This needs to be done in collaboration with the managers and the corresponding doctors. Furthermore, parameters of particular significance should be designated as key indicators in order to stress urgent business fluctuations. This is one factor that will simplify matters for employees to provide an insight in the daily business.

Testing and interviews detected that usage of a golden standard as point of comparison clarifies the direction of outcomes. Likewise is it of great interest for the user that data tables are presented above or beside corresponding graphs. Testing showed that presenting a data table below the graph that needed scrolling created confusion and was less user-friendly. Testing also showed that graphs with percentages are harder for the team to digest.

5.2 Health ICT

Prior studies have noted the importance of improved case records and according to Raptis' awarded paper of electronic software in hospitals, *"electronic handover can reduce medical errors through better continuity of care and therefore reduces patient morbidity and mortality"* [Raptis et al., 2009]. This study supports Aravind's work of improving the quality of case records through benchmarking.

The use of information and communication technologies for health, also know as eHealth, represents one of the key instruments for health care. eHealth has already been proven valuable, particularly in global health challenges such as emerging epi-

demics or the health consequences of natural disasters [Dzenowagis, 2005].

David W. Parke II, MD, chief executive officer of the American Academy of Ophthalmology claims that their database that enables benchmarking of their own care is a fantastically powerful tool that will stimulate improved quality of eye care. Furthermore the database assesses their quality of care rates and studies best practice through which ophthalmologists can develop a strategic plan for improving patient outcomes [Miliard, 2013].

5.3 Benchmarking in Health Care

Benchmarking is a valuable technique for quickly lifting the performance of an organisation and pushes the boundaries of best practice, which create opportunities for continuous improvement and development. The potential of benchmarking in the health service has been developed from the quantitative measurement of performance and consideration of processes to the qualitative attainment of best practice around patient experience [Kay, 2007].

Chapter 6

Conclusion

This study has been carried out as a proof of concept with few parameters on the glaucoma clinic on four of the tertiary hospitals. The hypothesis of the concept was that a business intelligence system in a web interface would connect Aravind's different hospitals and enable benchmarking across Aravind's clinics. This report's initial question was to investigate to what extents a business intelligence system could improve the organization.

This report has proven that it is achievable to develop a scalable open-source web platform that enables benchmarking in real-time. This study has also proven that Aravind's data of performance indicators supports this kind of benchmarking and therefore indicates that a complete implementation is feasible. However, it not possible to make any conclusion of the outcome from an online benchmarking since doctor Krishnadas emphasized that it is actually during the physical meetings that the teams push themselves to investigate areas of improvement and decline.

Even though the interviews were few in quantity and could not serve as statistic material, they were powerful enough to indicate possible impacts of the developed system. One conclusion of these indications is that data of performance indicators can easily be compared on a hospital level. Secondly indicates the interviews that a complete implementation on the glaucoma clinic is essential to obtain sufficient evidence for any conclusion.

This study has also indicated that benchmarking in health care can improve medical outcome through sharing of best practice and improved effectiveness. Research has also indicated positive outcome from development of information technology in health care.

6.1 Recomendations

It is recommended that future development of this web platform is carried out within the framework described in this report. A complete implementation also require precise definitions on how comparison will be done. Therefore is it essential that managers and doctors are involved in the development.

Furthermore, is it recommended that a focus group is used for evaluation in a iterative process. It is also recommended that higher quality of statistical material is collected through testing of a complete prototype parallel to an ordinary evaluation cycle.

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Interviews

Dr. Krishnadas,*Head of Glaucoma and Director-Human Resources*, 2015-05-11

Mr C.Gnanasekaran, *Manager - Operations and HR*, March-May 2015

Mr R.D. Thulasiraj, *Executive Director of Aravind Eye Care System*, 2015-05-12

Appendix A

PHP script

```
<?php
$h = $_GET['h'];   // Hospital value  e.g Madurai
$p = $_GET['p'];   // Parameter value e.g New_OP
$sp = $_GET['sp'];  //Start Period
$ep = $_GET['ep'];  // End Period

$con=mysql_connect("localhost","root","atillo1337")
or die("Failed to connect with database!!!!");
mysql_select_db("projectAE");
$sql = mysql_query('SELECT PayCampFree, SUM('.$p.') AS '.$p.'
FROM Service
Join Clinic on Service.ClinicID = Clinic.ClinicID
WHERE Hospital="'.$h.'" and StartPeriod ="'.$sp.'" and
EndPeriod = "'.$ep.'"
GROUP BY PayCampFree');

$rows = array();
$table = array();
$table['cols'] = array(
    array('label' => 'PayCampFree' ,'type' => 'string'),
    array('label' => $p, 'type' => 'number') );

$rows = array();
while($r = mysql_fetch_assoc($sql)) {
    $temp = array();
    $temp[] = array('v' => (string)$r['PayCampFree']);
    $temp[] = array('v' => (int)$r[$p]);
    $rows[] = array('c' => $temp);
}
```

```
$table['rows'] = $rows;
$jsonTable = json_encode($table);
echo ($jsonTable);
?>
```

Appendix B

Google Chart

```
google.load('visualization', '1', {'packages':['corechart', "bar", "table"]});
function drawChart(hosp, param, SP, EP) {
  var xmlhttp = new XMLHttpRequest();
  xmlhttp.onreadystatechange = function() {
    if (xmlhttp.readyState == 4 && xmlhttp.status == 200) {
       var jsonData = xmlhttp.responseText;
       var data = new google.visualization.DataTable(jsonData);
       var options = {
          title:  hosp+',   '+param,
          width: 400,
          height: 240,
        };

        // Instantiate and draw our chart, passing in some options.
       var chart = new google.visualization.PieChart(document.getElementById(hosp));
       chart.draw(data, options);
    }
  }
  xmlhttp.open("GET","adgDate.php?h="+hosp+"&p="+param+"&sp="+SP+"&ep="+EP,true);
  xmlhttp.send();
}
```