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Master Degree Program in

Information Management

Cost Analysis in Dentistry

Implementation of a Business Intelligence Solution in a dental clinic to perform cost analysis using stock details

Tomás Simões da Silva Vieira

Project Work

presented as partial requirement for obtaining the Master Degree in Information Management

NOVA Information Management School
Instituto Superior de Estatística e Gestão de Informação
Universidade Nova de Lisboa

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Cost Analysis in Dentistry

Implementation of a Business Intelligence Solution in a dental clinic to perform cost analysis using stock details

by

Tomás Simões da Silva Vieira

Project Work presented as partial requirement for obtaining the Master's degree in Information Management, with a specialization in Knowledge Management and Business Intelligence.

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July, 2024

STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration. I further declare that I have fully acknowledged the Rules of Conduct and Code of Honor from the NOVA Information Management School.

[Lisboa, 17/07/2024]

ABSTRACT

The dental clinic industry has experienced significant growth over the past decade leading to fierce competition among small and medium-sized enterprises and national/internation big players. This competitive environment has called for better practices in management especially in smaller clinics that traditionally relied on qualitative management approaches. In the fight for survival, smaller companies were forced to make management efforts that they were not used to. It is when Business Intelligence takes place. A business intelligence solution (BIS) will be set up to help dental clinics enhance cost analysis by utilizing data from Customer Relationship Management (CRM) systems and management softwares. The main aim of employing a BIS is to bring a revolution in this area leading to better insight concerning financial issues at clinics and detailed cost analysis for different cost segments. By focusing on the financial data generated by this solution, the project aims to provide clinic managers with the tools needed to make data-driven decisions that can optimize operational efficiency and financial performance. The results demonstrate the potential of the solution where managers were able to really understand the exact cost of each segment needed for understanding.

KEYWORDS

Business Intelligence; Cost Analysis; Dental Clinics; Data-Driven Decisions; Business Intelligence Solution; BIS

Sustainable Development Goals (SDG):

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LIST OF ABBREVIATIONS AND ACRONYMS

AKA	As Known As
BI	Business Intelligence
BIS	Business Intelligence systems
CRM	Customer Relationship Management
DSRM	Design Science Research Methodology
DSS	Decision Support Systems
DV	Data Visualization
DW	Data Warehouse
ETL	Extract, Transform and Load
FK	Foreign Keys
IM	Information Management
KPI	Key Performance Indicators
OLAP	Online Analytics Processing
SMEs	Small and Medium Sized Enterprises
SSIS	SQL Server Integration Services
STG	Staging Area

1. INTRODUCTION

Business Intelligence (BI) is part of this era as being one of the main base concepts to have in mind in decision-making. Nowadays companies don't stick only to past events but also to past and current data, with a view to further business improvement. However, this data only has value to decision makers when accessed, managed, and transformed using BI solutions. Here it is when the organizations realize the full potential of BI (Watson & Wixom, 2007).

1.1. RESEARCH CONTEXT AND MOTIVATION

Dealing with all data available is hard and sometimes unfeasible to a human being, and dentistry is not an exception. Dentistry is a practice that deals with a lot of data daily, from medical information (patient consultation, data communication with prosthetics, suppliers, and others) to financial data (costs, and other financial data). As medical information is part of the practice itself, its use and handling are crucial for the course of treatments, meaning data is put to use, however financial data has not been the main target of interest or focus by managers of these type of companies, that can bring meaningful impact in the decision-making process. A study carried out by two professors of Universidade do Algarve along with the order of portuguese dentists (Ordem dos Médicos Dentistas (OMD)) pointed out that the lack of cost information on the part of clinics can make good management practices unfeasible in the long term (Coelho & Peixinho, 2021).

Small and Medium Sized Enterprises (SMEs), specifically, small and medium sized medical dental clinics, suffer from a non-beneficial issue when it comes to management that can create long term issues, as this type of companies tend to have a closer relationship with the customers, with suppliers and even coworkers, that tend to translate in a more qualitative management, based on what you see and experience, instead of a quantitative based management, based on real statistics (Itanyi et al., 2012). Another reason is that this types of companies normally don't do managerial accounting since it is not mandatory like financial accounting, however this branch of accounting is responsible for analyzing internal costs, assisting management control and planning (Coelho & Peixinho, 2021) that due to clinic sizes, are all part of management. This situations can position this kind of dental clinics one step behind the competition, e.g. multinational clinics, also leading to economic and financial imbalances and poor decision quality.

This issues led to the development of this project that is held by the fact that this decision makers, as known as (AKA) managers of dental clinics, need to have a better overlook of their company, know better where to invest and where to reduce expenses to generate higher revenue by having analytical accounting. It is a factor of interest since several multinational dental clinics are starting to threaten the Portuguese market, and also some big national, which cause a reduction in number of patients in small and medium sized clinics and the

constant oscillations on the economical market that reduces the purchasing power of their clients, leading managers to create the need to put hands-on work and make some adjustments, meaningly on managing their data.

Coelho & Peixinho (2021) work focus on analyzing the costs of a standard clinic, where information from the generality of clinics is retrieved and set to determine what is the average clinic in Portugal concentrating on one of the biggest and with higher impact characteristic, the number of dental cabinets inside a clinic. Their line thinking will be taken into consideration and incorporated inside a new strategy, a business intelligence solution, where it will be possible to have an automated process of cost analysis by type of treatment.

1.2. RESEARCH FOCUS AND OBJECTIVES

To deal with this, inserted in the areas of study of this master's program, and having with background the work developed by Coelho & Peixinho (2021), this project aims to focus on the improvement of decision-making process in small and medium sized dental clinics using Business Intelligence Solutions (BIS) built on data generated by Customer Relationship Management (CRM) Programs and Management Softwares of Dental Clinics, not applied to a standard clinic, but to a real clinic. This way it will be possible to understand some financial factors with a focus on cost analysis per treatment.

To answer this need, the following research question was formulated: *How to improve decision making processes of dental practitioners and clinic administrators, focusing on cost analysis, using a business intelligence solution?*

For this purpose, two research objectives were set:

Objective 1: Create a business intelligence solution that provides data analytics and visualization tools to enable data-driven decision-making within dental clinics.

Objective 2: Investigate how the implementation of the solution affects the decision-making of dental practitioners and clinic administrators in terms of internal finances, particularly on cost analysis.

1.3. DATA SOURCES

To perform this project, it was needed to have a clinic that is inserted into the typology of SMEs and that can be used as an example. Having this in mind a small dental clinic transactional database was used, counting over 3000 clients and more than 4000 appointments per year. All data is generated by a management software that has been in use

since 2011, but due to privacy and competitive concerns, the data in use will be ranged from 2012 until 2019.

1.4. PROJECT METHODOLOGIES

As stated, data analysis in dental clinics, majorly in financial terms, is becoming increasingly important for the operation of a company. To perform this analysis, a business intelligence solution will need to bring information on how well a clinic is performing, focusing majorly on costs and profits, and helping managers take decisions based on data. To better understand the development of each step of this project, I will follow the six steps design science process mentioned by Hevner and Chatterjee (2010) and further explored:

- Problem Identification and Motivation: address competition, economic challenges, patient shortages, and missed appointments in the dental sector with financial data processing.
- Definition of the objectives for a solution: Develop a BIS for internal costs using data from management and CRM softwares.
- Design and Development: focus on financial data to identify cost patterns.
- Demonstration: create mock-ups and use Power BI for user-friendly dashboards displaying clinic financial data.
- Evaluation: Assess the solution's effectiveness by comparing decision-making before and after implementation.
- Communication: Present project outcomes, limitations, and future work development.

This work is divided into sections, starting first with an introduction to the reviewed literature where the key aspects that this project was based on such as Business Intelligence, Data Visualization, and Design Science Research Methodologies will be instituted. After this brief presentation the development of the project itself will be given in the Methodologies section with a later result and discuss analysis. Finally, a conclusion and further development work will be presented.

2. LITERATURE REVIEW

This project's focus is on Data-Driven Decision Making and the surrounding aspect of Business Intelligence (BI) where dashboarding, information management, information visualization, among others is inserted into.

2.1. BUSINESS INTELLIGENCE

The intelligence of the business started to be introduced by Luhn (1958), where he started to dig about the concept of "business intelligence system" and came out with a set of definitions that turned out to be the right path to today's knowing and understanding of BI, "the objective of the system is to supply suitable information to support specific activities carried out by individuals, groups, departments, divisions, or even larger units". Later on, in 1989, Howard Dresner (a former analyst of the consultant Gartner Group) coined the proper concept of Business Intelligence that considered it to be an umbrella term since it was "a set of concepts and methods to improve business decision making by using fact-based support systems" (Power, 2007). Some authors follow the same idea declaring that is a broad term that aggregates a set of technologies such as data warehousing, data mining, online analytics processing (OLAP), decision support systems (DSS), among others (M.-K. Chen & Wang, 2010), displayed on *Figure 1*.

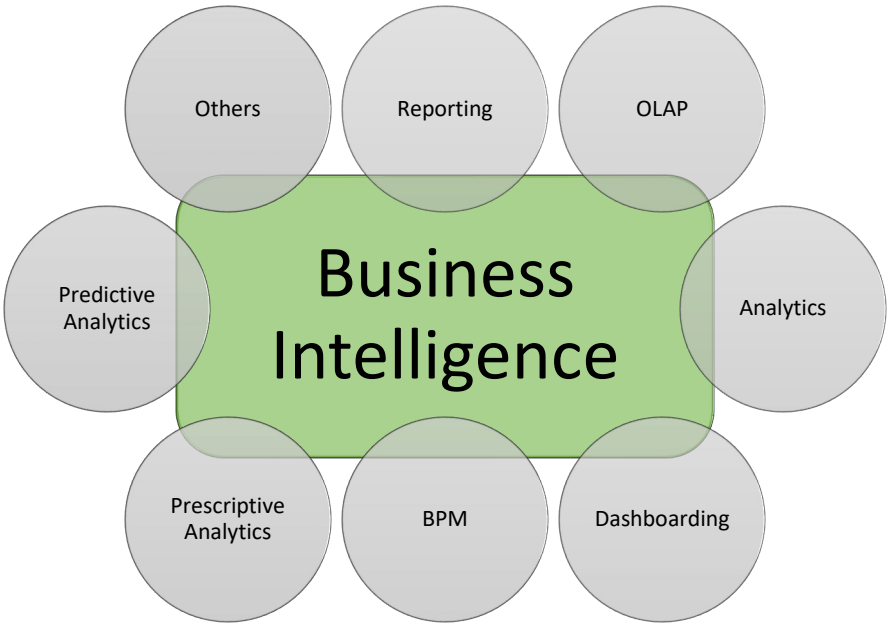

Figure 1 - Business Intelligence Technologies

2.1.1. Architecture

Typically, and referencing Vercellis (2011), a BI architecture is composed by three big components: data sources, data warehouses and data marts, and business intelligence methodologies. Although this project won't focus on data marts itself, it is important to understand that each component plays an important role in the development of a solution based on BI in different ways. Starting with the data source, here it is where the data is originally located, and it comes in various types and formats needing to be transformed and gathered using tools to extract, transform and load (ETL), a step that will be performed in the Staging Area (STG), and then loaded into the data warehouse (DW). To conclude the process a reporting software, namely Power BI, will read the DW and generate the desired reporting and analytics. After this it will be possible to apply the methodology proposed to procced with the analysis and support the decision makers (Vercellis, 2011).

In Figure 2 it is possible to understand visually a typical data flow that a BI project uses, this project only differs on the source, that it will only integrate data from an operational system. This process is especially important since the base objective of it is analyzing the costs of a dental company.

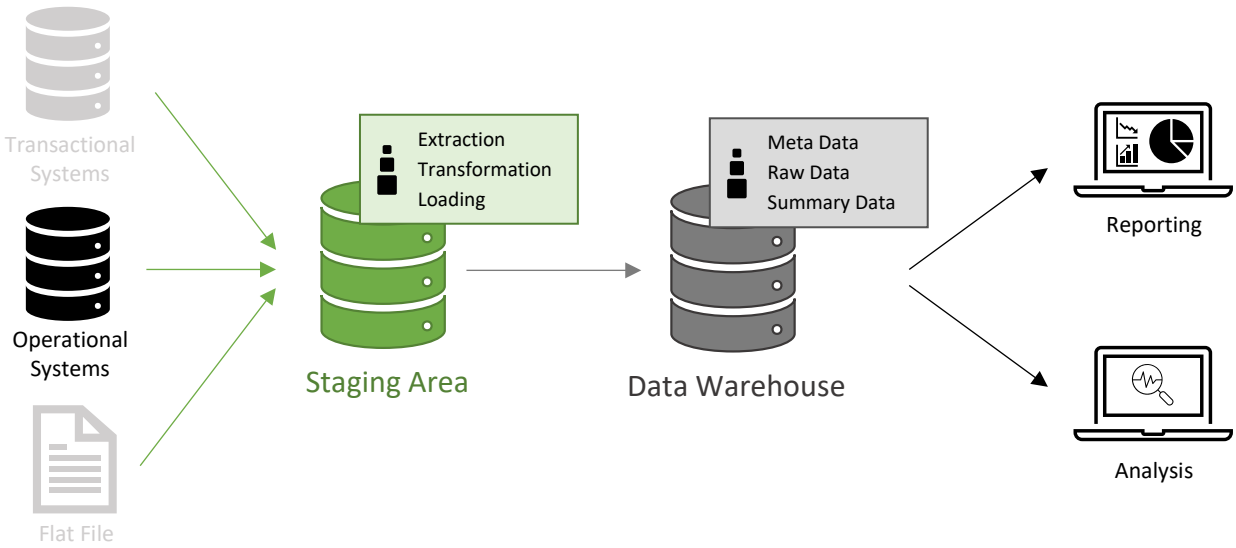

Figure 2 - Data Process Flow

2.1.2. ETL process

The ETL process is crucial, and it is the first step after extracting data for analysis. According to Demarest (1997) it is where the developer takes the most effort of the whole project, up to 80%. The original data source comes from management software, and it has a straightforward

working, anytime a new transaction is registered, whether it is in stock or a sale, or whenever an appointment is created, the system generates data (Figure 3). This type of data is the one which will be used later in the ETL process to populate the DW.

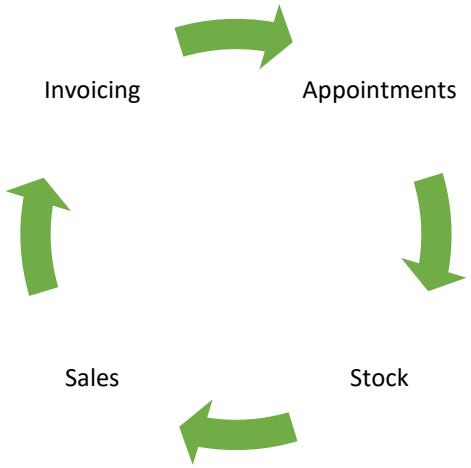

Figure 3 - System Generation Data

ETL, once built accordingly to the business needs, is an automated process that automatically extracts data from the data source into a staging area, that proceeds with all the transformations needed, and then loads these freshly clean data into the DW. For better understanding, each step is described below:

- **Extraction:** this phase is responsible for bringing the data from the sources and convert them into a single format (Kakish & Kraft, 2012) to a so-called staging area, an intermediate step where data is temporarily stored to perform the needed changes. There are two possible ways of extracting data (Kakish & Kraft, 2012):
    - Full extraction: when data is completely extracted from the source;
    - Incremental extraction: when data is partially extracted from the source but respecting the data already extracted before, meaning only altered or new data will be extracted, thus not incurring duplicate data extraction.
- **Transformation:** the transformation stage involves, among others, data type transformations and cleaning techniques, like remove duplicates, data type conversions, combining data from several sources, granularity definition, slowly changing dimensions (El-Sappagh et al., 2011), and mostly assigning the corresponding keys ensuring data integrity (Kimball & Ross, 2011). These keys are the ones responsible for connecting all data for further analysis.
- **Loading:** this step is when data will be loaded into the data warehouse. Identical to the extraction phase, it can have multiple methods such as full load, or incremental load. It can also have a distinct synchronization times depending, once again, on the business needs ((Kakish & Kraft, 2012; Kimball & Ross, 2011).

2.1.3. Data Warehousing

A data warehouse can be defined as being a "subject-oriented, integrated, time varying, non-volatile collection of data in support of the management's decision-making process" (Inmon, 1996). It is a space where various types of data are gathered with a view to performing a reporting and/or analysis of them, whether data comes from a transactional or operational databases or even a flat file (refer to Figure 2).

In the context of dental clinics, a DW can integrate data from various operational systems, including appointment scheduling, patient management, inventory, and billing systems. This integration allows clinic administrators to perform comprehensive analyses and brings several benefits (Figure 4), such as (Demarest, 1997; Gauzelin & Bentz, 2017; Wexler et al., 2017):

- **Operational Efficiency:** by streamlining data management processes, a DW reduces time needed for analysis and reporting. This efficiency allows staff to focus more on patient care and less on administrative tasks.
- **Cost Analysis:** facilitates detailed cost analysis, helping clinics understand the financial aspects of different treatment and procedures. This understanding can lead to better budgeting, cost-saving measures, and overall financial management.
- **Improved Decision-Making:** provides a comprehensive view of the clinic's operations, enabling data-driven decision-making with the help of dashboards and visualizations, making it easier for clinic managers to monitor performance and make informed decisions.

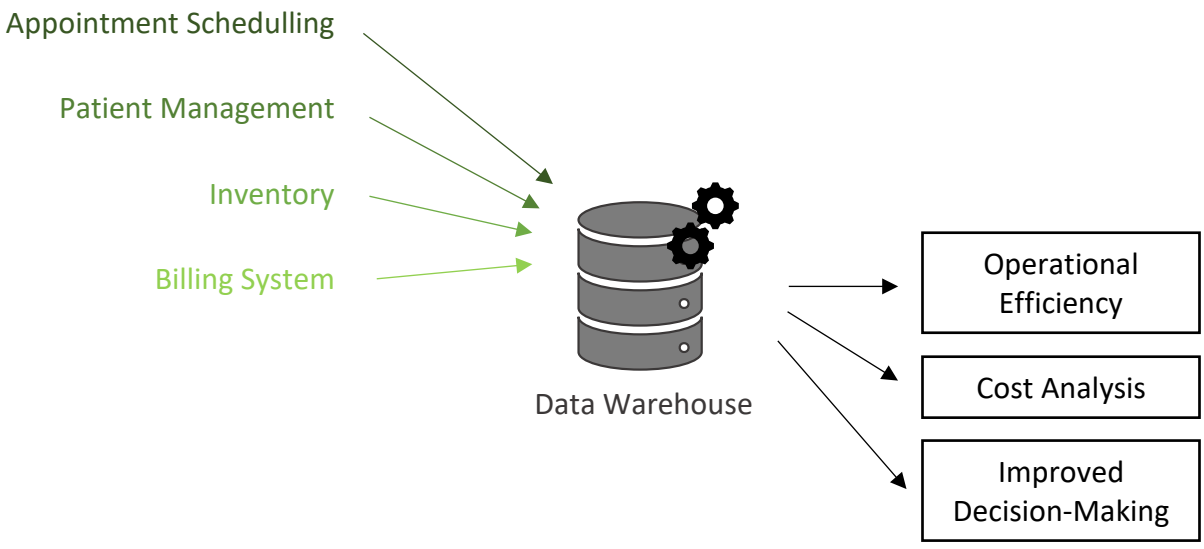

Figure 4 - Integration of data inside a DW and the resulting benefits

2.1.4. Business Intelligence Systems

Nowadays, BI is defined as being a powerful asset “as information has been identified as the most valuable asset of a company, it is a fundamental resource for its development” (Tavera Romero et al., 2021). It is designed to portrait the business dynamics of an organization, developing accurate visual understanding of the entire company with information gathered from multiple sources, with a main objective of supporting managers on their decision-making process, in line with the project, delivering information “at the right time, in the right format and to the right people” (Jordan & Ellen, 2009), for the reason that better information leads to better decisions, and better decisions improves competitive advantage.

Following the ideas introduced by the authors above it turns easier to understand why it is relevant and important to implement a BI solution inside clinics inserted in SMEs, helps putting into action a valuable asset (data), portraits the dynamic of the company visually (using dashboarding), reduces work time (transforming a time-consuming process into a relatively quick one), with a view of support decision-making. Power (2007) also states that “In general, business intelligence systems are data driven DSS”.

Business Intelligence systems (BIS) use data analysis and knowledge management to collect, store, and process complex data into useful and relevant information and is assembled in four big fields: analysis (data mining, OLAP, etc., refer to Figure 1), monitoring (dashboards and scorecards), reporting and prediction, essential tools to better understand business information and their surrounding environments, providing evidence on what, why and how an event happened (Gauzelin & Bentz, 2017). Further, a new classification was proposed by Delen & Demirkan (2013), based on three groups: descriptive, predictive, and prescriptive. The descriptive group analyzes what has happened, the predictive group forecasts what will happen, and the prescriptive group recommends what should happen in order to guide decision-making under strategic goals (Delen & Demirkan, 2013; Rouhani et al., 2016).

Although this is all part of BIS, the Descriptive part is the one which will be the focus of this project to support and give understanding to decision makers about the importance of variance in data and how does it impact in the finances of the company by analyzing past data. This way it will be possible to identify cost variation over the time, giving managers accurate information to support their decisions (Delen & Ram, 2018).

2.1.5. Data-Driven Decision Making

Making decisions implies knowing what happened and what is happening now to generate alternatives and choose among them, and to accomplish this we need information. Nowadays, CRM programs and management softwares generates enough data that can be transformed into information, helping to give managers a whole different point of view of their business, and totally influencing their action.

Previous tests have shown that using quantitative analysis and information for decision-making can effectively improve performance, efficiency, productivity, DM and cost reductions, among others (Jalil et al., 2019; Tavera Romero et al., 2021). This is the focus of the project, aiming that with the termination of it, managers could use a quantitative based analysis.

2.2. DATA VISUALIZATION

Data Visualization (DV) is the most important part of all the data-driven decision making. It is where value is delivered, where information is displayed graphically simply and straightforward (Sinar, 2015). It is possible to consider data visualization as being "functional art" according to Cairo (2012), because it is "something that achieves beauty not through the subjective (…) but through the careful and restrained tinkering of the engineer".

There is not a unified concept of DV, but combining ideas from several authors it can be defined as being the process of using visual elements, such as graphs, charts, maps, or images, to explore, understand, relate, and communicate data (C. Chen et al., 2007; Keller & Keller, 1993; Ramly et al., 2012).

For a dashboard to be useful, practical and give the correct information for DM, it is important to build it correctly without distortion (Ramly et al., 2012). All the information needs to be displayed according to the end user's needs enabling a correct visual display of analytics and quick retrieve of insights to guide decision making process. A dashboard should translate the current situation of the organization's internal activities, using for example Key Performance Indicator (KPI), and should always follow structure directives. It is important to choose the right colors, the right chart type, the scale and even the description is important, giving users the context of the information.

Choosing the right colors and display type, specifically, are key factors to a successful dashboard. Colors should be chosen carefully among different visualization types and elements, according to the end-user needs, for example if it is needed to present sequential data, a color must be picked with different tints to give the idea to the user that the data is sequential; if we mention about a categorical variables, different colors should be chosen to distinguish each one of them; and last but not least, when displayed diverged information, we should set two colors with different tints, creating a visual scale (Wexler et al., 2017). Figure 5 is a visual representation of what was mentioned.

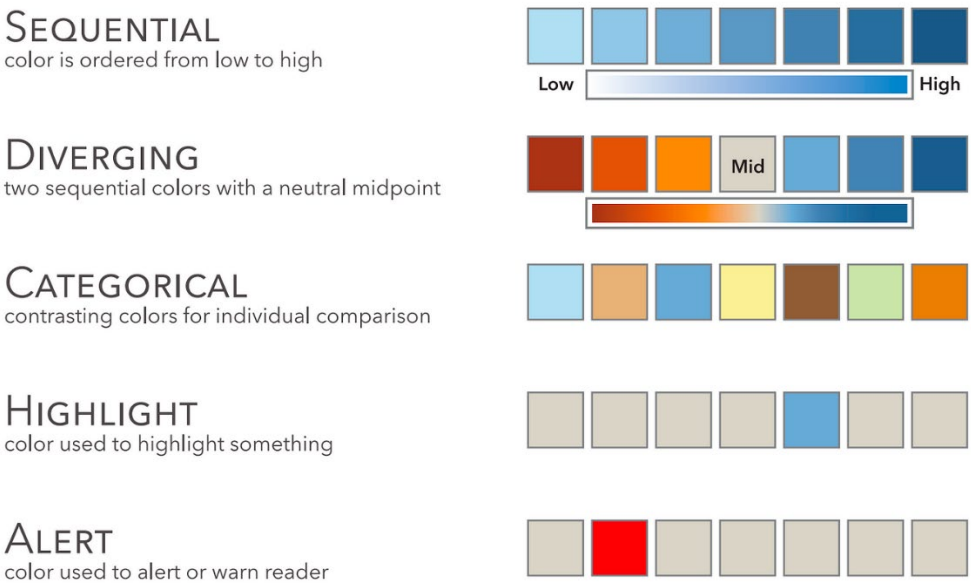

Figure 5 - Colors use in Data Visualization

Note: From "The big book of dashboards: visualizing your data using real-world business scenarios" by S. Wexler, J. Shaffer, and A. Cotgreave, 2017, Wiley Publishing. (Wexler et al., 2017)

Selecting the correct visualization types depends on what needs to be presented. As shown in Figure 6, there as 4 types of visuals (Lundblad, 2015):

- Relationship: helps understanding how independent variables relate to each other, for example, a scatter plot can show the correlation between two variables, like heigh and weight.
- Comparison: recognizes how two or more sets of data compare to each other, for instance, a bar chart can present differences between different categories, like sales by product.
- Distribution: this type of data visualization shows how different sets of data are spread over other distribution, such as a histogram, it can show the frequency of values in a specific range, namely age groups.
- Composition: indicates how a set of data is made up of smaller divisions, via illustration, a stacked bar chart can demonstrate the breakdown of values within each category, like revenue by product and region.

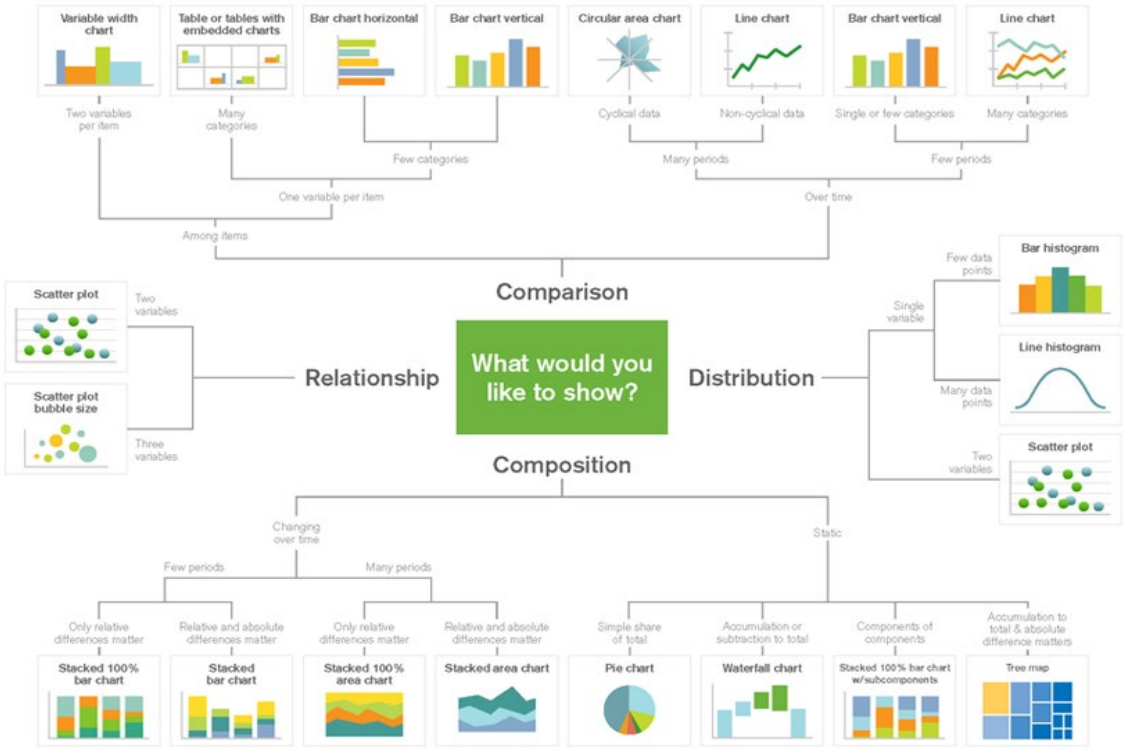

Figure 6 - Types of data visualization

Note: From "Third Pillar Of Mapping Data To Visualizations: Usage" by P. Lundblad, 2015 (https://www.qlik.com/blog/third-pillar-of-mapping-data-to-visualizations-usage). Copyright © 2024 QlikTech International AB (Lundblad, 2015)

The setting of the whole dashboard is also an important topic. Knowing where to position the displays according to the level of importance is crucial and as a simple rule, the most important thing needs to be displayed in the center-middle of the screen, it is where the person that is analyzing will look at for the first time. After this, things should be displayed, according to level of importance, from the top-left to the bottom-right corner of the screen, following the numbered example from 1st place (most important information/people is attention is drawn here) to 5th (least important area) on Figure 7.

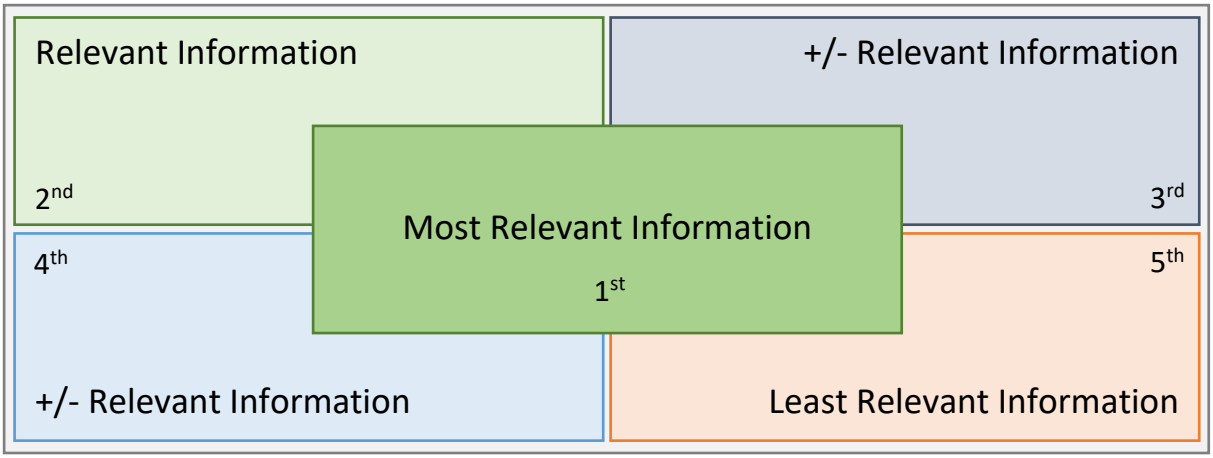

Figure 7 - Dashboard relevant areas

It is important to know that complexity leads to misunderstanding and too many unnecessary elements displayed can lead to confusion, what is called a Clutter. For a dashboard to successfully present insights it must be simple, have a spaced design and it should be tested before the final user interacts with it, ensuring that it works properly, and it is effective.

3. METHODOLOGY

This project follows the Design Science Research Methodology (DSRM), with the goal to analyze costs and improve the decision-making process in small and medium sized dental clinics using Business Intelligence Solutions built on data generated by Customer Relationship Management (CRM) Programs and Management Softwares of Dental Clinics. A checklist defined by Hevner and Chatterjee (2010) targets everyone who wants to achieve a similar nature type of this project, which is the following:

1. What is the research question (design requirements)?
2. What is the artifact? How is the artifact represented?
3. What design processes (search heuristics) will be used to build the artifact?
4. How are the artifact and the design processes grounded by the knowledge base? What, if any, theories support the artifact design and the design process?
5. What evaluations are performed during the internal design cycles? What design improvements are identified during each design cycle?
6. How is the artifact introduced into the application environment and how is it field tested? What metrics are used to demonstrate artifact utility and improvement over previous artifacts?
7. What new knowledge is added to the knowledge base and in what form (e.g., peer-reviewed literature, meta-artifacts, new theory, new method)?
8. Has the research question been satisfactorily addressed?

Financial accounting is mandatory for most companies, but it neither translates into nor allows for the evaluation of internal conditions necessary to determine and control cost by cost objective (Caiado, 2011, as cited in Coelho & Peixinho, 2021). This is where the need of having a managerial accounting shows up, focusing on costs by cost objective assisting decision makers (Coelho & Peixinho, 2021). This project had this into consideration with a view of creating a artifact capable of managing all the data used in the managerial accounting deliver a realistic and accurate solution to the problem of needing to understand and know different types of specific costs when taking decisions in a dental clinic. This means that using the solution created it will be possible to perform this job instantly and analyze all the needed data when taking financial related decisions of a clinic.

According to Hevner and Chatterjee (2010) and having this project in mind, the design science process follows six steps (Figure 8):

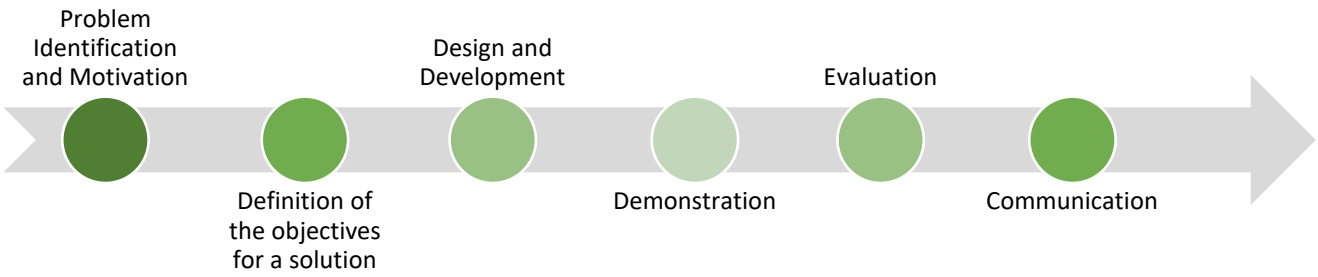

Figure 8 - Design Science Process

- Problem Identification and Motivation: with big competition threatening the sector and the several economic problems that the dental sector is facing, lack of patients, and/or appointments skipped, are a big deal and have huge impacts on the financial state of these companies. Data processing, in financial terms, would bring several benefits to better understand where and what to do to improve and reduce costs, based on real data.
- Definition of the objectives for a solution: the main objective is focused on building a BIS that can handle data generated by management softwares and/or CRM programs, creating a model to perform cost by cost objective analysis internally.
- Design and Development: the design of this solution will be focused on financial data to understand certain patterns of costs, with a view to general financial improvement.
- Demonstration: several mock-ups will be produced ensuring a simple and informative solution dashboard, using for this purpose Power BI software to display the data retrieved from a management software of a clinic inserted in the sector of SMEs.
- Evaluation: after conclusion, an analysis of the solution will be performed to understand if it answers the mentioned needs, comparing how decision making was made before, and how the solution influenced it after the implementation.
- Communication: after the conclusion of the evaluation phase a presentation will be made along with the limitations of this projects and potential future developments.

Following this idea, the process of achieving an accurate, reliable, and informative solution will be described across this chapter, as long as all the steps to acquire, transform and deliver the data.

It is important to take into consideration that this solution will use data from a company that has been chosen for being a model of the sector, although every further implementation of this solution should be analyzed and built according to each company is needs.

3.1. PROJECT REQUIREMENTS AND INFORMATION

To start building a BIS it was important to understand the data source. This data was acquired from the management software of a Clinic, which we must keep anonymous and call Clinic A, that has been in use since late 2011. All functionalities of the software weren't all put in use since the beginning, that is the case of stock management that was put in use in late 2019. Due to this reason, the data range in use will be filtered out between 2020 and 2022.

With the aiming of having a tool to determine and analyze the internal costs, focusing on stock, each specialty, and how this cost analysis impacts the decision-making and consequently clinic's activity, some questions came across with this information, and they were considered as business questions and as being the development focus. Namely they are:

How much does it cost for a patient to sit down on the dentist's chair?

In the dentistry sector, this is a very important question to know, it is called the "Patient Basic Kit" (PBK) or in Portuguese "Kit Básico do Paciente". Normally, small and medium sized dental clinics have no clue how much does a patient costs just to sit down. This is a matter of importance because a patient sitting involves disinfection of the space, the paper bib, a cup, a napkin, the disposable saliva suction tube, the sterilization of the materials, a mask for the doctor and another one for the assistant, as well as a pair of gloves for each, and the paper tray, and all of this involves costs.

What is the average cost per type of treatment?

Each specialty has different needs of materials, thus having different costs. Analyzing stock values and usage information it was possible to know the cost of each type. Two different treatment cost analysis were developed, as an example: complete fixed self-ligating maxillary braces, and implant surgery.

In this analysis only material costs were taken into account, meaning that all fixed costs such as electricity or water, amortization and wear of materials will not be considered. The reason is that the management software doesn't store information regarding this variables, that kind of data should be imported from an external source, which won't be the focus of the overall project. The project focused on analyzing data that was imported from the management software of clinic A.

This reports should have the capability of having a live connection to the original data source, with the possibility of analyzing each day, week, trimester, and year, meaning have a wide date granularity.

3.2. STOCK COST ANALYSIS

To properly perform the cost analysis, it was needed to create metrics and factors of identification for the different types of costs, either the basic kit, or the cost analysis by type of treatment. Each one of them needed to take into account the type of materials in use for their practices and are described below.

3.2.1. Patient Basic Kit

Following the line of thinking introduced before, patient basic kit (or Appointment basic kit cost analysis), has a huge importance in the management of a dental clinic since it is the base cost of all treatments, it is imperative to know this type of cost to perform the following analysis (Coelho & Peixinho, 2021). It is important to understand the real costs of the material doctors put in use to perform their job. Though it is vital to focus on the materials costs and on the fixed costs (such as electricity and water bills), however since this is a cost analysis focusing on the materials and the stock presented in the software, only material costs were analyzed.

The patient basic kit is composed by a set of materials, that with the help of Clinic A team and the study conducted by Coelho and Peixinho (2021), it was possible to determine the exact types of materials and their quantities that are need and used in Clinic A. This are displayed in Table 1:

Table 1 - Product Types and Quantities for PBK

Product	Quantity
Cup	1
Disposable saliva suction tube	1
Gloves	4
Masks	2
Napkin	1
Paper bib	1
Paper tray	1
Surface disinfectant (ml)	8
Surface paper cleaning (40 cm)	1
Zig-Zag Paper	6
Sterilization Sleeves (33 cm)	1

After knowing this information, it is important to understand the database presented. In Figure 9 it is possible to see that the field unit price (*PREZZOUNITARIO*) is available, although, it is not the correct price of each one of the items described in Table 1, the values displayed correspond to the unit price of each one of the box. For example, the product displayed in the

figure is the disposable saliva suction tube, each box contains 100 tubes in it. For this purpose, each unit price needed to be split into the number of items that each box contains giving this way the correct item price, which was called ITEM_PRICE.

	ID_MOVIMENTOMAGAZZINO	ID_ARTICOLO	DESCRIZIONE_STOCK	QUANTITA	IMPORTO	PREZZOUNITARIO	DATA_STOCK	CATEGORIAMATERIALE
389	B31H1BDIE	8434309000119	Aspirador de saliva verde	1	2,0325	2,0325	2021-03-11 00:00:00.000	DESCARTAVEIS
390	E72HG7PAF	8434309000119	Aspirador de saliva verde	1	2,0325	2,0325	2022-07-14 00:00:00.000	DESCARTAVEIS
	REATTIVEVOCIPOSITIVE_SHIF71PJ	8434309000119	Aspirador de saliva verde	1	1,4848	1,4848	2020-10-14 00:00:00.000	DESCARTAVEIS
392	D1BBR8SJE	8434309000119	Aspirador de saliva verde	3	5,9092	1,9697	2021-01-13 00:00:00.000	DESCARTAVEIS
393	CDCG4DMIF	8434309000119	Aspirador de saliva verde	1	2,0325	2,0325	2022-01-12 00:00:00.000	DESCARTAVEIS
394	CE1HECJHE	8434309000119	Aspirador de saliva verde	1	2,0325	2,0325	2021-02-12 00:00:00.000	DESCARTAVEIS
395	C7BD0CLIE	8434309000119	Aspirador de saliva verde	1	2,0325	2,0325	2021-07-12 00:00:00.000	DESCARTAVEIS
396	C7BDMGQIE	8434309000119	Aspirador de saliva verde	5	8,9186	1,7837	2021-07-12 00:00:00.000	DESCARTAVEIS
397	EM2B27KJF	8434309000119	Aspirador de saliva verde	1	1,847	1,847	2022-10-14 00:00:00.000	DESCARTAVEIS
398	FABCG9IHE	8434309000119	Aspirador de saliva verde	1	2,0325	2,0325	2021-10-15 00:00:00.000	DESCARTAVEIS
399	FE29JLUSF	8434309000119	Aspirador de saliva verde	1	2,0325	2,0325	2022-02-15 00:00:00.000	DESCARTAVEIS
400	HO1GMYPPE	8434309000119	Aspirador de saliva verde	1	2,0325	2,0325	2021-12-17 00:00:00.000	DESCARTAVEIS
401	HL1IKQJPE	8434309000119	Aspirador de saliva verde	1	2,0325	2,0325	2021-09-17 00:00:00.000	DESCARTAVEIS
402	H6A9VFPND	8434309000119	Aspirador de saliva verde	2	2,9697	1,4848	2020-06-17 00:00:00.000	DESCARTAVEIS
403	I3CBZ6LOF	8434309000119	Aspirador de saliva verde	1	2,0325	2,0325	2022-03-18 00:00:00.000	DESCARTAVEIS
404	I42C08MCF	8434309000119	Aspirador de saliva verde	1	2,0325	2,0325	2022-04-18 00:00:00.000	DESCARTAVEIS
405	INAEEJVLD	8434309000119	Aspirador de saliva verde	1	1,4848	1,4848	2020-11-18 00:00:00.000	DESCARTAVEIS
406	1M1HKESJE	8434309000119	Aspirador de saliva verde	3	5,3511	1,7837	2021-10-01 00:00:00.000	DESCARTAVEIS
407	25CAF1LNF	8434309000119	Aspirador de saliva verde	1	2,0325	2,0325	2022-05-02 00:00:00.000	DESCARTAVEIS
408	312IX3OGF	8434309000119	Aspirador de saliva verde	2	3,4443	1,7221	2022-01-03 00:00:00.000	DESCARTAVEIS
409	1GCH2MJIF	8434309000119	Aspirador de saliva verde	10	20,7887	2,0789	2022-04-01 00:00:00.000	DESCARTAVEIS

Figure 9 - Original Dataset

3.2.2. Complete fixed self-ligating maxillary braces

Understanding the costs of materials for an appointment is important for several reasons, from budgeting purposes to treatment complexity. Using complete fixed self-ligating maxillary braces (“Aparelho fixo completo autoligavel maxilar”) as an example it is possible to understand that knowing the costs helps on the budgeting in a more accurate way, also having all the material discriminated for cost analysis will imply that staff uses the software to do stock management, making everything more controlled.

This evaluation has several materials needed to perform the work, and each one as its weight and value. To perform a complete self-ligating braces job, it will be needed polishing brush, prophylactic paste, acid applicator, phosphoric acid, applicator, adhesive, composite resin, self-ligating bracket kit, tubes, bands, round Niti arch wire, rectangular Niti arch wire, rectangular steel arch wire, spring, power chain, intermaxillary elastics and orthodontic wax, has described in Table 2.

Table 2 - Product Types and Quantities for self-ligating maxillary braces

Product	Quantity
Polishing Brush	1
Prophylactic Paste (g)	1
Acid Applicator	1
Phosphoric Acid	1
Applicator	1
Adhesive	14
Composite Resin	14

Self-Ligating Bracket Kit	1
Tubes	6
Bands	1
Round Niti Arch Wire	2
Rectangular Niti Arch Wire	2
Rectangular Steel Arch Wire	2
Spring	1
Power Chain	1
Intermaxillary Elastics	10
Orthodontic Wax	1

3.2.3. Implant Surgery

Similar to the previous case, an implant surgery involves several set of materials like topical anesthesia, articaine, scalpel blade, suture, compresses, needle, an implant and the screw, chlorhexidine, saline solution, an irrigation line for the serum, and surgical vacuum. Table 3 has all the products discriminated with the needed quantity.

Table 3 - Product Types and Quantities for implant surgery

Product	Quantity
Topical Anesthesia (25ml)	1
Articaine 1/100000	2
Scalpel Blade	1
Suture	2
Compresses	8
Needle	1
Implant with Screw	1
Chlorhexidine 0.2	15
Saline Solution (ml)	250
Serum Irrigation Line	1
Surgical Vacuum	1

All the materials that were described on Table 1 to Table 3 were considered combining the information from Coelho & Peixinho (2021), and from information retrieved from doctors of Clinic A.

3.3. ETL PROCESS

As mentioned in chapter 2, to develop a BIS, it is needed to gather data, perform the ETL process and insert data into a DW and then develop the proper reports. This project was developed with the use of several tools to analyze databases, transfer data from several locations to others, and create a visual representation of data. With this stated, Microsoft SQL Server Management Studio 18 was used to create the DW and STG through the creation of scripts, Microsoft Visual Studio helped with the ETL process as well as moving data from the source to STG and from there to the DW, and finally Microsoft Power BI that stayed responsible for reading all managed data and transform it into cost analysis visualizations.

3.3.1. Staging Area

With the goal to load the DW, the Extract, Transform and Load of data was performed with the help of Visual Studio, that runs in the SQL Server Integration Services (SSIS).

In the first place STG needed to be loaded, and for this purpose a direct connection was made to the data source. This data source, as stated, is from a dental management software, with a specific particularity of having an Italian dataset, once the company responsible for developing the program is Italian. It is a transactional database, in charge for storing company's daily transactions, and is separated into three different sources:

- DBDENT – stores patient information, appointments schedules, doctors' details, and information about stock, among other information not suitable for this analysis.
- DBESERCIZIO – here is the information regarding all the transactions in terms of stock, payments, and appointments.
- DBSTORICO – does not have any relevant information, since this database is responsible for ensuring data privacy only through a random separation of crucial data, like full name, thus complying with the GDPR. This means that this database only has parts of information majorly about clients, that with the right coding it is possible to decrypt it.

Having this, data will be gathered from DBDENT to retrieve the dentist, category of the materials, and stock information and DBESERCIZIO to retrieve the transactional data about the variables mentioned.

A calculated variable was created to settle the value of the variable ITEM_PRICE. This happens because, like stated, each pack or box of materials are not exactly the number of materials that are needed to perform a job, that way QNT_UNITS (Quantity Units) was created to report to the variable ITEM_PRICE the number of utilizations/units that each pack has. There were two approaches in the calculation of these values, ones were a simple division of the value of package unit price by the unit's quantity, for example: gloves, saliva suction tubes, etc., and

the other was a medium quantity usage as for example the sterilization sleeves. As displayed in Table 4, each item has different units or has length for different applications.

Table 4 - Description of each products units and measures

Product	Units/Usage	Unit of measure
Cups	100	units
Disposable saliva suction tube	100	units
Gloves	100	units
Masks	50	units
Napkins	100	units
Paper bibs	500	units
Paper trays	100	units
Surface disinfectant	320	usages
Surface paper cleaning	400	units
Zig-Zag Paper	200	units
Sterilization Sleeves	606	usages

3.3.2. Data Warehouse

Loading the DW is the final step of the ETL before moving to building visuals in Power BI. For this to be successfully loaded it is important that data matches the correctly designed format, something that is easy since most of the transformations were made in STG.

The DW model is focused on investigating costs, therefore a model was created to fulfill the business questions generated with dimensions such as costs, stock, and typology of treatments was created (Figure 10).

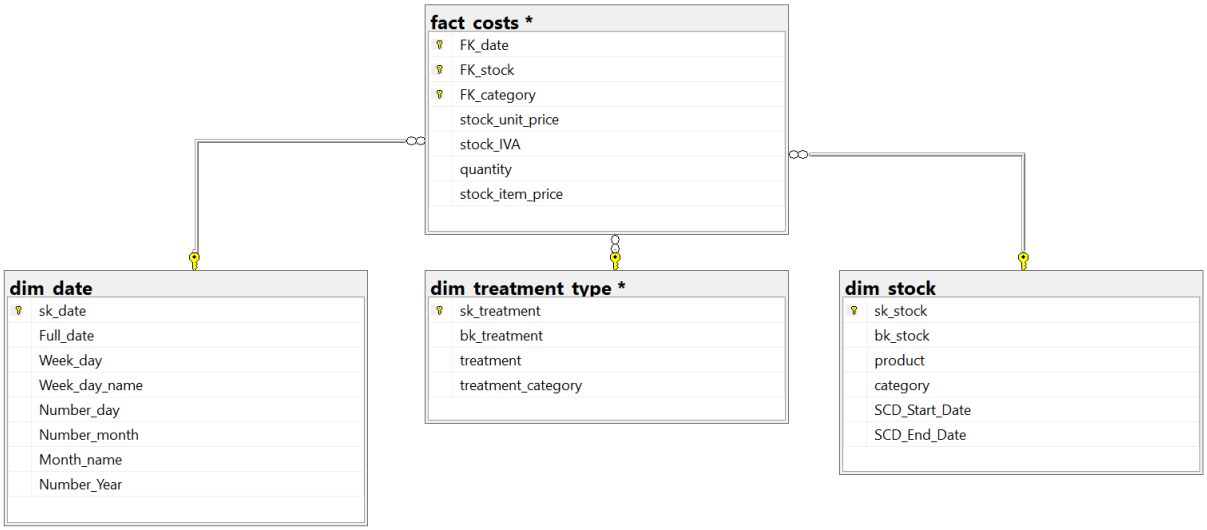

Figure 10 - Data Warehouse Diagram

This way it was able to analyze each treatment cost through different points of view, from a stock perspective, and from a treatment perspective.

4. RESULTS AND DISCUSSION

This topic aims to analyze the results of the implementation of the artifact and discuss the outputs. These results are displayed in dashboards after the implementation of BIS. It is important to take into consideration that the analysis of the results was made with a view of knowing what is happening in terms of costs.

All the results displayed bellow are specific of Clinic A. Even if all the analysis made are transversal to all clinics of the sector, there is not a possibility of displaying more generic results once the objective is to understand the "state of the art" of the company and, still, not optimize costs for now. This would be a future work development to take into consideration, after a full reorganization methods in company operations.

Figure 11 - Patient Basic Kit Visual

Figure 11 is regarding the patient basic kit, where it is possible to see the stock materials that have bigger impact in the cost, the name of all materials included in the basic kit and their average price, as long as line and stacked column chart that displays the average item price and the corresponding number of usages/units that each item has. The total cost of this analysis, in 2022, reaches 3,08€ meaning that each time a patient sits down on the dentist's chair costs 3,08€ in terms of material expenses to Clinic A. The items that have the bigger impact on this value are the gloves with 0,17€ each two pairs of gloves, and the surface disinfectant with 0,12€ per usage.

It is important to note that each year's total cost of PBK will be apart of all further treatment analysis since every treatment involves this materials.

Figure 12 - Complete fixed self-ligating maxillary braces

Figure 12 is regarding the analysis of a complete fixed self-ligating maxillary braces where it is possible to analyze that the item that has bigger impact in the total price are the brackets pack costing 55,11€. The total price listed is 244,37€, which is according to some calculations carried out by the managers of Clinic A, before this analysis.

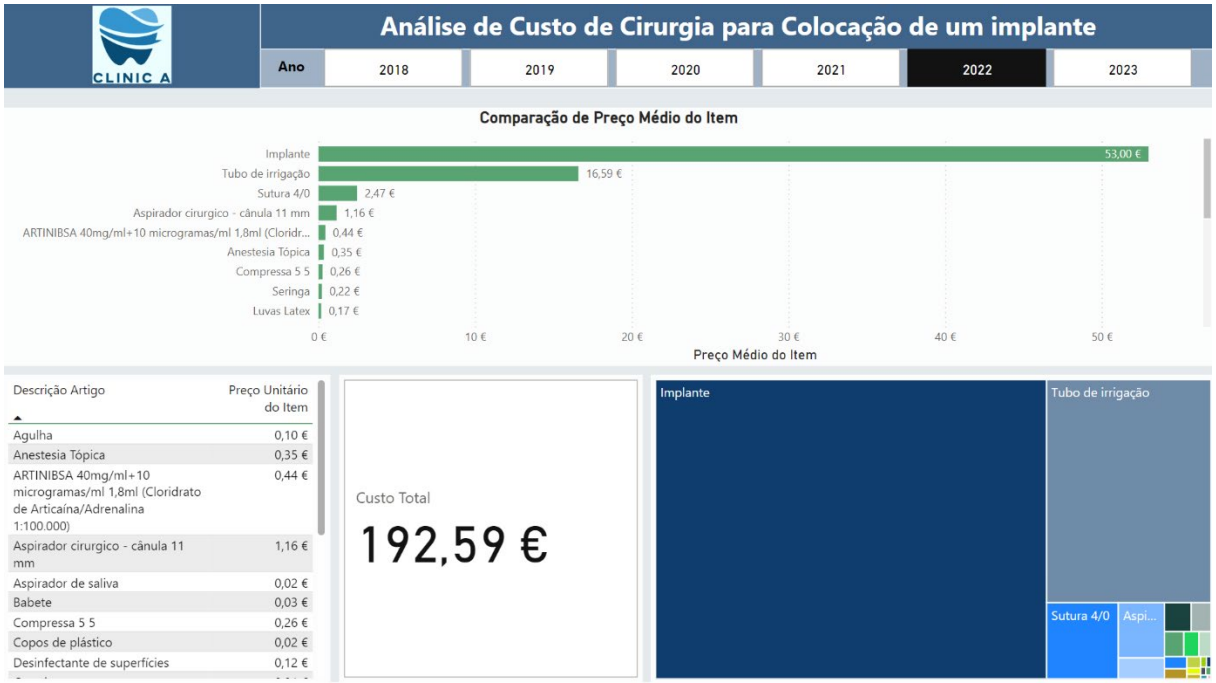

Figure 13 - Surgery to place an implant

Concerning Figure 13, it translates that in 2022, to make an implant surgery, the average price of each act is 192,59€, with implants having the biggest impact in the total value.

This results showed an accurate display of the cost directly related to the products in stock, making this artifact always up to date with new stock entries. It helped analyze the costs by nature, and by type of treatment.

With this charts it becomes easier to visualize the average cost of each type of treatment per year, making it possible to define different strategies for managers according to this information, for example increase/decrease costs of treatments.

The introduction of this solution in Clinic A led to a significant improvement in the decision making in terms of cost analysis, once after this implementation a redefinition in terms of financial terms were made to maintain the absolute amount of profit strategic settle by the clinic. Managers realized that more than 10 years have passed without updating the values of the appointments, even with the previous year's market fluctuation. This means that it gave managers a different point of view of their internal costs, and consequently making some changes to it.

After the decision makers used the BI solution developed there was an improvement in the administrators' working time. For example, the cost of sitting a patient on the chair was previously analyzed manually and only sporadically, giving now an on-time view of data.

Figure 14 - Values Comparison over time

In this chart (Figure 14) it is possible to understand that the costs of the PBK have varied significantly over the years, where 2021 is the year with higher material costs, namely because

of the last quarter of the year 2021. This significant increase in 2021 regarding 2020 and 2022 may be related to the pricing effects of COVID-19.

Referring to the category of materials the most expensive ones are the ones related to surgical medical acts, far followed by prosthetics and current oral healthcare ones.

On top of this, eventually, there is also the effect of inflation and the beginning of rising interest rates on the global economy. Despite this, in 2022 there was a significant reduction in the cost of PBK, despite the increase in inflationary pressure in the last quarter, in which the COVID-19 factor is replaced by the increase in the barrel of oil following the Russian-Ukrainian conflict.

For the final solution to work properly, many data preparation needed to be done, since data quality was relatively low. Missing data was not a relevant problem because, so no influences on the analysis happened. Some types of variables were created to be able to proceed with the analysis, as stated before, since other metrics were needed.

5. CONCLUSIONS AND FUTURE WORKS

The integration of a BI solution into dental practice management has demonstrated a substantial positive impact on the decision-making process. The findings of this thesis underscore the pivotal role of BI tools in enhancing the efficiency, accuracy, and financial performance of SMEs, namely small dental clinics. Administrators/decision-makers have leveraged the BI solution to optimize operations and reduce costs.

Despite the initial challenges in adoption, the long-term benefits suggest that the integration of BI solutions is a worthwhile investment for dental practices management. It is recommended that dental clinics consider the adoption of such technologies to remain aware of what is happening in their clinics, since one of the problems stated in the beginning was the fact that more than half of the clinics are not aware of the costs associated to the customers neither to each type of treatment.

As the healthcare industry continues to grow, the use of advanced analytics will likely become a standard practice. Future research should focus on refining BI tools to further support the complex decision-making processes in dental healthcare and explore their impact on patient outcomes and satisfaction. At the same time the introduction of new types of technologies and materials, normally associated with higher costs, leads to a necessity of higher control to monitor the costs and the revenues balance.

The artifact revealed that with the use of a BIS gets easier to make costs analysis and financial control. Although there are some improvements that could be made to make this work richer and robust, providing more accurate information. I am talking about including variables in addition to those considered in this project: staff costs, equipment and materials depreciation, general indirect costs of the clinic (costs associated to asset managements, maintenance, service suppliers and providers, partnerships, rentals, etc.). Including this variables and analyzing these other costs would display a more complete dashboard for managing a dental clinic.

This analysis, as stated, is focused on the understanding of clinics' "state of the art". While focusing on that analysis, further development should be focused on optimizing costs using cost optimization mechanisms and operation organization. This way it would not be only possible to understand what is happening with the clinic, but also make a further cost optimization analyzing all costs with a view to cost reduction. This would be the next step, but one does not forget the universe of low-sized companies in this market. It also depends on if a syndicate grouping a reasonable quantity of this type of companies in order to get size scale to improve such a program of cost management.

Related to the topic above, there is also another perspective that could be set and developed to create a better understanding of what could happen. In other words, the introduction of a simulation dashboard could bring valuable insights to managers that are not sure of what to

do. This way they could manipulate real data from their companies and add or subtract different percentages to their values and understand what would happen with the variance of the data. For example, picking on the Patient Basic Kit example, if there was a field where I could simulate what would happen, or what would this influence in the future if I vary the value? What would happen if the value were duplicated? Or if it were subtracted in 10%? All this variances would impact on the manager's decision giving this way a good feedback and analysis for them. The simulation part would be possible with the adoption of a second fact table that uses the data from the original fact table and modifies the values according to the end users' orders. If the end user wants to see what would happen if the value got duplicated, the system will read data from the fact table and duplicate the value to show the user the final simulation value. Resuming: bringing strategic management to this level of business.

There is also a suggestion for a future work development regarding the types of analysis that were done. Other points of view, such as the cost analysis by doctor or by dental office to have other perspectives understanding better where and what specialties and doctors have more costs.

In conclusion, the successful implementation of a BI solution in dental clinics represents a significant step forward in the mission for operational excellence.

This conclusion encapsulates the overall benefits and recommendations derived from the thesis project, providing a clear and concise summary of the results and discussions presented earlier.

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APPENDIX A

This is to certify that
Project No.: **INFSYS2024-6-246350**
Project Title: **Cost Analysis in Dentistry**
Principal Researcher: **Tomás Simões da Silva Vieira**

according to the regulations of the Ethics Committee of NOVA IMS and MagIC Research Center this project was considered to meet the requirements of the NOVA IMS Internal Review Board, being considered **APPROVED** on 6/24/2024.

It is the Principal Researcher's responsibility to ensure that all researchers and stakeholders associated with this project are aware of the conditions of approval and which documents have been approved.

The Principal Researcher is required to notify the Ethics Committee, via amendment or progress report, of
- Any significant change to the project and the reason for that change;
- Any unforeseen events or unexpected developments that merit notification;
- The inability of the Principal Researcher to continue in that role or any other change in research personnel involved in the project.

Lisbon, 6/24/2024

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