An Alternative Model to Estimate Annual Budget Through TDABC Methodology in Hospitals

José Luis Hernández Arredondo(✉), Elí Gerardo Zorrilla Uribe, and Zaida Estafanía Alarcón Bernal

Universidad Nacional Autónoma de México, Av. Universitaria 3000, 04510 Mexico City, Mexico
josepharredondo@comunidad.unam.mx

Abstract. This work responds the Mexico City's General Hospital "Dr. Manuel Gea González" need to identify the cost behind daily operative activities. Our objective is to improve the hospital's capacity to establish a budget for its operation, to comply with the federal government's request to operate free of charge for users. To achieve the objective the authors constructed a computerized costs system, using software resources owned by the institute, based on TDABC methodology (Time Driven Activity Costing methodology), which generates and allocates expenditures depending on the execution time of a process. Likewise, the use of fuzzy logic tools helps decreasing inherent uncertainty bring by the resources consume, typical of clinical processes. It was collected information related to medical supplies, human resources, equipment, and infrastructure expenditures. This work describes the approach and execution of a pilot test made in nine clinical areas of the hospital. Finally, some proposals can guide further system development.

Keywords: TDABC · Fuzzy logic · Relational databases · Supply chain management · Healthcare system

1 Introduction

The Mexican public health care system is currently saturated due to the increasing demand for medical services, mainly because the population is getting older [1]. Therefore, there is a growth in metabolic diseases in the last years [2]. In addition, the Covid-19 pandemic saturates the system and further strains the performance of the sector at all levels. On the other hand, medical infrastructure is living an evident stagnation [3] represented by little growth for public health (in 2019 was just 2.5% of GDP) [4].

In recent years, a new policy establishes that public healthcare services must be free of charge to users [5] and a minimal private investment in comparison to other economical sectors [6] has been made.

J. A. Marmolejo-Saucedo et al. (Eds.): COMPSE 2021, LNICST 393, pp. 28–44, 2021.
https://doi.org/10.1007/978-3-030-87495-7_3

These factors promoted the constitution of the INSABI (Instituto Nacional de Salud para el Bienestar) in 2020, which is in charge of providing healthcare services for people without Social Security. To achieve that, the INSABI requested the hospitals update consumption data to structure expenditures of medical institutions.

The hospital "Dr. Manuel Gea González" located in Mexico City, requests a budget to the federal government authorities annually and consequently enables every process execution inside the institute. Unfortunately, it lacks an internal team dedicated to control and monitor expenses and a suitable infrastructure that allows a constant information flow from the operative areas to the strategy board. Due to the hospital's complexity, it's hard to accurately determine all the costs involved and have a model which represents with better precision the institute's behavior.

Nowadays, the Mexican Institute of Social Security (IMSS) recommends the use of a costing model based on two approaches: first takes information in an up-to-down method and allocate total costs into productive areas (in this case, clinical departments) proportional to the volume of production, that means areas with more work, will have assigned more budget. The second part obtains detailed information from each operational department, guided by an Activity Based Costing (ABC), where every process mapped and then consumed resources allocated according to the specific needs of each one. In aggregation, we can obtain a more accurate model compared to using only one approach at a time. This methodology was established and explained in 2011 [7] in an attempt to standardize the way hospital calculate their annual budget.

The studied hospital belongs to the IMSS infrastructure, so it was crucial to implement the costing guide provided by the Institute. However, this approach has a high human and time resource consumption because usually, the staff has to dedicate a substantial amount of time to analyze and register the processes' performance. For that reason, in 2004, the Health Ministry designed and distributed a computational tool to help the cost estimation of hospitals based on Microsoft Excel [8]. Unfortunately, the program code is obsolete to modern software platforms and hard to reimplement to the hospital.

Usually, the healthcare institutions that do not belong to the IMSS infrastructure, have a different costing structure that is not standardized. This consists of an approach of the annual budget requisitions with a hybrid of the method applied in the IMSS and a Traditional Costing System, which implies the direct allocation of expenses to the given services and calculates the number of cases they had in a year and sum the overhead costs. This kind of structure implies a big accuracy error in the estimated budget.

Those are one of the main reasons the authors proposed a new structure, adapted to the hospital circumstances, to obtain data more easily from clinical areas, reduce the time that information is processed, and mainly, have more precision about the total expenses generated by the hospital, only using software resources owned by the institute because of the project's limited budget. The result was the development of three elements: first of all, the use of a methodology established by R. Kaplan in 2004 named Time-Driven Activity-Based Costing (TDABC)[9][1] which is characterized by determining expenses depending on the execution time of activities, where each one has a cost rate per unit of time; moreover, it was necessary to design and construct a database with formularies that allowed the capture of consumption data for all clinical areas; and third, all this conducted by an established plan from project management theory.

In this document, we explain some details of the mentioned system, from the theoretical approach to the computer program in charge of database management. In the next section, we will explain the TDABC theory and how it works in a variant oriented to the healthcare industry. In the same way, we will talk about the fuzzy inference used to diminish uncertainty, both on medical supplies consumption quantity and execution time for all the different processes. Later in the same section will be an application on "Dr. Manuel Gea González" hospital, where it talks about the method adaptations made due to the institutional context. In the Results section, we will discuss obtained values from the nine studied areas and particularities that emerged in each case, in addition to some data related to departments' efficiency. Finally, in the Conclusions section, we will describe implementation challenges the team faced, and therefore possible improvements in favor of system performance.

1.1 Previous Work

After Kaplan and Anderson created the TDABC method in 2004 [9] various authors put it into practice because of its implementation simplicity. TDABC is an evolution of the original ABC (Activity Based Costing) method [10] oriented to the manufacturing industry, but it turns hard to apply when the processes are not standardized (we can see a deep comparative between methods on del Rio [11]). Demeere uses TDABC, which in 2009 [12] apply the methodology to a clinic in Belgium (to five different departments), the study highlights the great adaptability, as well as the vision granted to the hospital's strategic level. After, in 2011 Kaplan [13] launch a variant of the method made specially to hospitals, centered on following patient's "cycle of care", where integrates all the processes used by patients in a specific medical condition. This method was applied at the University of Texas MD Anderson Cancer Center in 2010 by H. Albright [13, pp. 61–64], where we can find the importance of physicians' awareness about the cost born from treating patients.

Dr. Öker [14] points the need to increase productivity in the healthcare sector. For that reason, she concludes the TDABC method as an alternative to face a fast-changing reality and a tool with great precision obtained from allocating costs in just one variable, time. McLaughlin [15] sees an opportunity to redesign processes in mutual agreement because everyone sits on the same table analyzing better ways to improve the system. Bakhtiar Ostadi proposed on 2019 [16] an approach to TDABC, where use tools from Fuzzy inference to obtain resources cost, time, and capacity values. The goal is to reduce uncertainty and

[1] an evolution of ABC costing.

have more reliable information. On the other hand, A. Martin [17] emphasizes the challenges of implementing it because it is imperative to have an updated resource platform also, the natural resistance from healthcare providers being transparent in reporting their daily tasks. Finally, G. Keel & et al. [18] revised 25 TDABC applications, as same as Ganesh [19], independently they conclude the difficulties determining indirect costs (there is no way of proceeding on Kaplan original method). Nevertheless, they can identify some benefits like operational improvements, reduction of resource waste, and lead time decrease. An approach to defining a starting work structure is the Guide to Public Health Supply Chain Costing [20], where we can find some steps to consider when someone estimates costs on health care institutions.

2 Method

2.1 Technological Tools

The constricted resources and budget of the hospital let available just a few resources for innovation, especially the technological infrastructure. Nevertheless, there was the availability of a Microsoft license and the feasibility of a friendly user interface. The project required to be enhanced using technological tools, that would improve the method to be organized and automatized, so it can make the data link without the common employee error interaction. With that in mind, it was analyzed the use of Microsoft Access as the most reliable solution to attend all the demands. As well as it has the most advantages: solid database software structure, availability of the license in all the computers, feasibility to be managed through a central server connected to all the devices in the hospital, and the easiness of customer usage.

The lack of knowledge and experience in developing technological tools that could improve the process realization was a major constraint in the hospital employee and administrative capabilities. Administrative departments could facilitate the few available resources, but there was not much time they could invest. Therefore, the authors developed a project plan to build an Access database that stores and computes the core information. We expected two different users: medical employees (who would feed the database) and control users (who would manage stored data). Hence, the construction of Access forms through Visual Basic code was critical. So that users were able not only to give data but also interact with the available information. In addition, the database is attached to an Excel sheet, built to combine the core information inside the Access database about processes and resources consumption relationships. Hence, it can be computed more efficiently than inside Access and would display the results of the method showing strategic financial information and becomes more user-friendly with the chief executives of the institution for its interpretation and usage.

In resume, the method was enhanced by the usage of:

Access database obtains, manages, and controls the information about resources' consumption in the hospital. Excel form analyzes, computes the

Access' database information. In consideration of the designed costing method and displays strategic information about the hospital financial requirements.

2.2 Application

The hospital used to work with two flow stream budget revenue, one from cost per service charged to the patients, and the other was an annual budget allocated by the federal government. The new public healthcare policies detonate a need to restructure the service to achieve universal free cost healthcare services. Therefore, the government set new tasks to capture and analyze the expenses of each institution that give attention to people without social insurance.

Nevertheless, the growing and aging population of Mexico represents a latent problem. In addition to the increase of non-transmissible metabolic diseases, such as diabetes and hypertension. That requires high levels of investment and enhances the capability of the public healthcare services throughout the years. Those demands will stretch the current system and the need for a new methodology to know how much expenses allocate in each type of disease [21].

The risk involved in a wrong executed budget could put at risk all the hospital's operability. Hence, they know that with the new government policy, they shall adequate their assigned budget. Nevertheless, they had no infrastructure and human capabilities to develop an advanced costing system, only the traditional time sequence forecasting method, which has proven wrong several times. Hence, the authors developed an adaptation from the TDABC methodology according to the hospital's resources and capabilities. In addition, it was applied project management theory to define and plan task sequences, goals, and objectives expected from this project. As well as quality, stakeholders, and a work breakdown structure that allowed control and project performance follow and their stakeholders, decreasing the level of project execution uncertainty.

In the case study, the authors and the hospital chief executives decided to apply the method in a pilot group considering nine clinical departments: Anesthesiology, Blood bank, Stomatology, Internal Medicine, Neonatology, Nutrition, Ophthalmology, Rehabilitation, and Urology. In addition, of support and administrative departments of the hospital that influences the resource consumption interaction of the clinical department. The four analyzed resources for the costing system were: infrastructure, human resources, equipment, and medical supplies. The new method based on the TDABC technique consists of the following steps:

- Mapping Activities
- Resources Group identification
- Departments total cost
    - Contracts assignment
    - Human resources assignment
    - Infrastructure assignment
    - Equipment classification and assignment
    - Cost assignment
- Department's workforce capacity

– Capacity rate
– Processes execution time
– Cost per activity

Mapping activities is the first step in the TDABC technique used in this article. It was analyzed all the activities that the different departments execute. Those processes were reviewed, analyzed, and modified to obtain the most representative processes of the patient care chain of each department, considering the type of capabilities that each service offers to the patients. The processes were reviewed considering the following question parameters

– The process is still functional?
– The frequency of process realization is still representative?
– Is still the best available process for the cycle care of the patient? Is it antique or old?
– The process is too general, it encloses too many procedures or processes that will be better as separate processes
– The process is very similar to a different one, causing redundancies
– It is possible to fusion similar processes as one, because the activities are very similar or are part of the same clinal procedure
– The process has very diverse outcomes hanging on the type of patients, it will be representative to classify this process in consideration of the type of outcome.

This mapping process was managed by a healthcare professional of each department in which the method will be applied.

In the Resource Group (RG) identification the aim is to enclose all similar costs that can exist between services. A resource consumption classification was made in consideration of the hospital functional structure, type of processes, and clinical departments. Hence, the criteria used for this step was to classify all the processes in consideration of their department and the amount of time and resources consumption. This step analysis shall be made with the collaboration of healthcare professionals, healthcare executives of the hospital, and the implementation team. As a result, it was established 5 RG: Surgical, Outpatient, Diagnostic, Ambulatory Surgery, Therapeutic.

In terms of standardized procedures, the authors suggest establishing for each of these RG a description, so it becomes easier the next processes classification step. After the RG elaboration, all the processes of the 9 clinical departments were classified according to the established Resource Groups, which depends on the clinical nature of each process. This classification is called "divisions", so it becomes easier to distinguish the consumption of available resources in a general way, that can differentiate between big cost differences.

Until here, it was structured the elements that will work as the drivers to have general components with the right level of specificity in the amount of resource consumption, with the cost as the main parameter of segregation. Therefore, the method is specific enough in the big difference, but as general as it can be to make it easier and cheaper the implementation. The resources assignment in each department is key to the good implementation of the method. It is required good communication and collaboration between the administrative departments to have access to all the financial and resource information. As it was required information in terms of contracts, employees, procurement, equipment, inventory, infrastructure, and medical supplies.

Through the Plan and Integration Department of the general hospital, we obtain all the required information of:

- Human resources
  - Assigned Area
  - Salary
  - Schedule and Laboral days
  - Type of professional
- Inventory
  - Clinical mobiliary
  - Medical equipment
  - Office equipment
  - Nonclinical mobiliary
  - Vehicles
- Infrastructure
  - Building plans
  - Assigned area to each department
- Contracts
  - Maintenance
  - Procurement
  - Outsourcing
  - Insurance
- Medical Supplies o Prices per product and per minimum quantity.

The human resources were classified according to the type of professional and salary differences. The salary of the existent types of employees in the hospital was reviewed. Therefore, since it existed not a significant difference in the amount, the professionals were assigned according to the hospital information, where it was specified the quantity of each professional that each department has. So, the data was upload to the database, then the logic of it, classified and assigned the type of professional, the quantity and the salary per year and per employee of all the professionals of each department.

For the inventory was designed a classification system in terms of the type of equipment, classified by the description, usage, and complexity of technology. It was established 5 types of equipment:

- Life support equipment
- Surgical equipment
- Therapeutic equipment
- Diagnostic and monitoring equipment
  - Low technological complexity

    - Medium technological complexity
    - High technological complexity
- Others
    - Clinical mobiliary
    - Nonclinical mobiliary

The hospital inventory describes all the material assets, where are placed, and when they were acquired. The depreciation value allocates as the only way to assign a cost of the equipment. Nevertheless, because of the public healthcare constraints, most of the hospital equipment is quite old, causing that it was required to modify the standard depreciation values Thus, it was established to consider all the equipment with less than 20 years of being acquired, and the following depreciation values: 10% for others and therapeutic, 12.5% for surgical and low and medium technological complexity diagnostic and monitoring equipment, 20% for life support and high technological complexity.

The parameters were uploaded into the Access database and the system classifies the data given according to all the requirements established and extracts the depreciation value and assigned the cost to their corresponding department.

Meanwhile, the contract information was segregated and assigned, according to the contract description and type of service, through an Access form in a manual way. Since it exists different procurement, outsourcing and service provider the assignation was supervised by personal with hospital's administrative knowledge. The main criteria were that the cost of the contract was attributed to the corresponding department that manages, deploys, or consumes this type of resource/service. This amount shall correspond to an annual operating cost sum, the database makes the relation of the specific contract and the department assigned.

The difference in terms of hospital infrastructure costs is quite significant since we have common areas that are used not only for administrative and support departments but also in outpatient processes. In contrast, the infrastructure used for specialized clinical processes such as surgical, diagnostic, and hospitalization procedures is more expensive than the common areas. As a result, two types of infrastructure: general and clinical areas should exist.

In this concept was attributed the cost that corresponds to the depreciation of the infrastructure, maintenance employees and contracts, insurance, electrical and water fees, so on and so forth. Those concepts build the general fee of the infrastructure that was divided by the total amount of square meters of the hospital. The process was automatically achieved through the database and obtains an amount of money per square meter.

The cost of medical gas contracts, clinical infrastructure depreciation, and clinical contracts was summed by the database and divided by the total square meters of clinical areas of the hospital. Operating rooms, hospitalization areas, and diagnostic/laboratory areas build the clinical areas. Then, was obtained a medical per square meter fee. The general square meter fee acts as the base for the clinical fee since it makes use of all the common infrastructure of the hospital.

The clinical per square meter fee was the result of the sum of the general fee and the medical per square meter fee.

The information of the medical supplies was realized in a previous stage of the work and was only extracted uploaded to the database. This information corresponds to a fuzzy logic procedure for estimating the medical supplies consumption of all the processes of the clinical department. The medical supplies correspond to medicament, reactive, materials and all the medical resources that are used in a disposal way to provide the clinical service.

All the cost of human resources, equipment, and infrastructure was automated summed by the database to each one of the corresponding administrative and clinical departments that were considered in the pilot group. The cost of each one of those elements attends to a one-year usage period. In other words, one year of salary, one year of depreciation, one year of medical supplies usage (according to the number of procedures that were notified in a year of biostatistics), one year of infrastructure usage. The data was uploaded and warehoused in the database for future disposal. In the next step, we will start talking about the main denominator and control element of the method.

As told, it has been built and enclosed most of the characteristics and elements that have a direct cost associated with providing healthcare services to each of the administrative and clinical departments. Nevertheless, it is critical in the original TDABC to have a time control element that provides the cost segregation detail needed, in terms of the real utilization of all those resources. The cost rates assume this role, they are based on the time utilization of each process. But first, it is needed to know the cost rate of each department, and here is where the great differentiation point of each department is built since we make it throughout the available workforce time of each department.

At this point we need to define the criteria used for considering or not the workforce, for this case of study it was stated the following criteria for considering it as part of the available workforce time: All the healthcare professionals that work directly with the patient. In other words, all the professionals that their interaction adds value to the patient in the care chain, e.g. physicians, nurses, auxiliary clinicians, so on so forth. Those with administrative or support roles were not considered for the workforce availability of the clinical departments, but all the employees were considered in the administrative department's workforce time.

Differentiate the workforce in Theoretical time which is the sum of all the Laboral hours of the selected professionals time, and a real-time that employs the theoretical time but with a factor of discount that represents the idle time of the employees such as mealtime, bathroom, and other activities that are not related with the patient but are made during the work time.

The database information about the human resources includes the data about the days they work and the time they need to work it was easier in the database to make the sum about the available workforce time per department in consideration of the described criteria. Nevertheless, in the hospital, there are 3 types of contracts: interns, base, and confidence, and four turns: morning, evening, night, and special. Each one of these with different employee benefits in terms of non-working days and holiday periods. So, through an Excel algorithm that analyzes the type of contract from the employees established all the Laboral days that they should work. With the information of the Laboral days per year and Laboral time per day per professional was established the theoretically available workforce time per year and per employee. Then, all the employee's time information of each department was summed in the database and was given the theoretical workforce time per year and per department. Secondly, must be applied the discount of idle time, in this case, was established that the real workforce time is 80% of the theoretical time, so this value was applied through the database to obtain the real workforce time in hours per year and per department.

At this point, the database has collected all the information about the operational direct cost and available workforce time of each department per year. Therefore, the first calculation of the method was obtained: the capacity rate. The capacity rate is defined as the cost per unit of time of executing any activity in the department. It is obtained through the division of the sum of all the operational direct costs of the described resources per year divided by the total real available workforce hours of the same department. This is the moment in which the database links the information to an Excel spreadsheet that was designed to extract and make de division and obtain the capacity rate of each department per hour since it was the case main time unit driver. The spreadsheet obtains automatically all the information and calculates it for all the departments.

The process execution time is one of the core activities and most demanding processes of the method. Acts as a core element to the required execution time of all the processes of the clinical departments. The Access forms worked as the interactive interface where the healthcare professional of each department was assigned to introduce and feed with their time data the system. The time needed for each process of their respective department. To avoid uncertainty, it was applied a fuzzy inference method with the usage of a triangular function. Therefore, it was demanded that they provide 3 values of the time employed: an optimistic time when the patient responds well and the process is quite easy, the meantime in their experience, and the fatalistic time when the patient complicates and does not respond well to the process and requires the most time of it. The mathematical method was expressed on the Excel spreadsheet and obtain the data from the Access forms that compute all the information to obtain the fuzzy inference value of time of each process. In addition to the process's time, it was also used the fuzzy inference on the medical supply resource consumption to avoid the uncertainty of the specific amount of those supplies used in each process. The fuzzy inference makes use of the Yager index through the expected value to give an approximation of the behavior of the expected number.

The assignation of the cost of each process represents the final step. Escalate it to the operational cost per department is critical to obtain a budget estimate. Hence, it was designed the logic of it. As it is known the operative processes work as a combination of direct and indirect activities. Those indirect can be defined as support processes, e.g. biomedical assistance, or a surgical or ambulatory department intervention on the process execution. To make representative those support areas process in the interaction with the main clinical processes it was assigned to a hospital administrative and clinical professional to fill an interaction table where it was defined all the supportive areas that were found in the hospital. Then, the professional had to link for each process which of those areas were related in the process and an estimated percentage. As a result, is built the relational table that represents the usage of the support department of all the processes from the pilot clinical departments.

Once more is applied the Resource Group definition, at this point in the method we have a general fee of cost per unit time of each department. Until now is explained how was made the cost segregation of each resource group in terms of the equipment used for each process. In other words, as an example, if we are talking about a surgical process it will correspond to a surgical RG. So, its fee will be based on the general cost of the department plus all the equipment and infrastructure required for a surgical process (clinical area and surgical equipment in this example) and a new total cost of the surgical RG of this specific department is obtained (based on the general operating cost) that is different from the resource used for a therapeutic process. This is a Resource Group cost segregation it's made automatically in the cost rate step but is explained now to be more representative about how the costing process is differentiated. Hence, even when the method looks too general it was designed to make the representative differentiation in key steps.

With that in mind now we have cost fees per hour per each department's Resource Group. So now in the excel spreadsheet, the cost is built. For every process of the clinical departments make the following procedure:

- Extract the type of RG of the process
- It extracts the rate of the specific department Resource Group
- Analyze the relational table and extracts the name of the support departments that are related to the process
- Extract the rate per hour of those related departments
- Sum the rate per hour of the specific department Resource Group of the process and the rate per hour of the related support departments and is obtained a process rate value
- Obtain the information of the fuzzy inference time value obtained for that specific process in hours
- Multiple the process rate value and the fuzzy inference time value to obtain an expected cost per process realized
- Is extracted the amount of money required in medical supplies for this process and is summed to the cost per process and is obtained a total cost per process
- Information from biostatistics about the quantity of realized processes per year of this type is extracted
- The information about the quantity of made processes per year is multiplied by the total cost per process and is obtained an estimated operating process cost per year.

This procedure is realized for every process in the clinical departments and then it is summed all the estimated operating process costs per year of all the processes of each department to obtain an estimated annual operating cost of the department. Finally, we summed all the clinical departments' annual operating costs to the cost of the administrative departments (e.g. directions, financial, legal, etc.), and an estimated budget can be estimated for the hospital.

3 Results

Taking into consideration the resources from contracts and ledgers before mentioned, we distributed expenses into two groups; direct costs, which include all the processes around the nine studied clinical areas, these activities treat patients directly in one or another way; on the other hand, we have indirect costs, which include all administrative work and activities not making patient's direct care attention. In the first group, the model calculates a need of MXN 315,231,406.45 (USD 16,369,364.83)[2] to provide the services from the nine areas for one year; for indirect costs, it takes MXN 203,658,187.54 (USD 10,575,580.68)for operate normally along one year; in total the hospital expenses are MXN 518,889,593.99 (USD 26,944,945.52)[3].

For more detail we will show particular quantities for each clinical area:

Table 1. Costs and efficiencies related to each clinical area

Department	Annual cost (MXN)	Efficiency (%)	Cost rate
Anaesthesiology	$83,277,829.87	101.99	401.31
Blood bank	$48,957,638.95	206.63	455.78
Stomatology	$51,949,286.39	252.85	483.74
Internal medicine	$ –	–	683.57
Neonatology	$54,121,884.38	44.75	1855.90
Nutrition	$37,652,114.93	292.85	266.83
Ophthalmology	$17,684,786.10	23.18	445.10
Rehabilitation	$8,267,668.78	87.41	309.90
Urology	$13,320,197.04	56.66	893.27

The second column costs of the Table 1 come from the sum of all processes performed in one year, 2019 in this case, so main expenses are on Anaesthesiology area being of MXN 83,277,829.87 (USD 4,324,458.64), the minimum was

[2] Using the annual 2019 average dollar exchange rate of 1 USD = 19.2574 MXN, year of analyzed hospital's data.

[3] It's important to say that this number does not represent all expenditures the hospital have along one year, because we are just taking into consideration costs from the nine clinical areas studied in this pilot test.

Rehabilitation with MXN 8,267,668.78 (USD 429,324.24). Also, the third column represents the calculated departments' efficiency, i.e., the quotient between the available theoretical workforce and the actual work done by the areas (we have to remember this variable is obtained directly from the time expended on processes of each department), all of this represented in time units. In cases where the efficiency is higher than 100% means that the area is executing work that exceeds their capacity in terms of workforce or machines, the strategic board has to implement actions to improve their work, that is the case for Stomatology with 252.85% or Nutrition with 292.85%. On the other hand, we have percentages less than 100% in this case the area have more staff than they need for their daily activities, in this case, we have to look out Ophthalmology having 23.18% or Urology at 56.66%. The adequate interpretation of the efficiency results needs are dependent of the accuracy of the needed time for process execution. Finally, in the last column, we can appreciate the rate cost per time unit, which shows how much cost change depending on the medical supplies, staff, and equipment usage between departments. This information provides an outlook of where it is draining the hospital income.

Table 2. Annual cost of processes

Process	U. cost (MXN)	Annual frequency	Annual cost (MXN)
General Anaesthesia	1,567.75	7968	43,721,471.83
Serologic test	1,818.67	4794	31,677,944.85
Orthodontic treatment	2,063.49	7125	29,894,754.65
Sedation	6,476.24	1200	20,205857.09
Enteral nutrition	2,447.26	3284	19,442,270.90
Parenteral nutrition	2,033.21	2660	13,070,181.98
Membrane rupture treatment (infection)	26,837.49	50	12,881,993.26
Intrathecal block	1,429.98	3093	12,826,472.84

Starting from the Table 2 above, we can observe some of the most expensive processes annually, highlights "General Anaesthesia" presumably due to their supplies cost. Remember, the annual cost of procedures is defined by multiplying the rate from the area and the frequency the task is executed along the year (also, the sum of supplies cost utilized is counted). It appears to be some consistency in costs around 11 million MXN annually, except for the upper elements which, consume a considerable part of the operational budget (19–43 million MXN annually). In some cases, the annual cost rises because of the high number of process repetitions during the year; in other cases, the elevated cost of a unitary process translates into a substantial annual cost.

As we can see, this method saves expended resources on implementation because the algorithm distributes and estimates consumption from each area depending on declared information in accounting books. We achieve this by combining data from statistical and accounting departments with detailed supply consumption data directly from the clinical workforce. Instead of mapping every activity (like the ABC method) and attach their resource use, the method manages all expenses in "Resource Groups", which have a rate cost per use time. If we have the execution time from each activity, we can obtain the total cost from processes and departments. Also, the computational tool is in charge of doing the calculations, allowing physicians to concentrate on minimal administrative activities but delivering accurate and updated data for better decision making.

In addition, the use of fuzzy logic tools improves the system performance, especially for the healthcare environment, because usually, it is hard to define standards on medical practice due to inherent uncertainty. Compared to traditional ABC or Monte Carlo simulation, these tools behave more efficiently and reflect activities under uncertain conditions adequately, that is because this approach is easier to understand for physicians when is expressed in terms of critical, common, and optimistic scenarios. All of this fits perfectly with the public healthcare sector circumstances where the demand is increasing at a high rate, the diseases are becoming more expensive and the institutions' performance is more challenging due to clinical and management problems. Therefore, this kind of work will help all the public healthcare institutions where the budget is constrained and does not have the flexibility to invest time and money in developing new operating strategies.

3.1 Discussion

There is no Internal Medicine information in the Table 1 because no data was delivered to us about the annual quantity of processes by the department when we write the official report. Moreover, we saw some inconsistency in the data previously acquired, being necessary to redefine resources consumed and establish a new mapping in the area; something impossible at that moment because Mexico was on his worst stage of the COVID-19 pandemic, and all activities from Internal Medicine were interrupted and focused attending the patients.

The equipment depreciation method also was modified compared to the traditional method used in the hospital, there is a lot of equipment that should have been replaced long time ago, nevertheless, the constraints in resources forces to the institution to make use of this equipment and increase expected service life time of it. The depreciation was adapted to the accountability reality of the institution, so there was equipment that could make a cost difference between the processes.

When we presented the results to hospital authorities, they disagreed about the Neonatology efficiency results because there is one of the busiest specialties in the hospital. So, after reviewing the information provided from the area, we concluded there are other processes or activities they do but don't report because it is an emergency area and results in complicated perform bureaucratic tasks due to the nature of their work.

On the other hand, we had problems with supplies but mainly with General Anaesthesia. Because we use a hospital register that they already have for all the medical supplies commonly use, so in many cases, there was no relation between the quantities they use and its units (in other words, the supply units, like milliliters or grams, didn't match consistently with the quantities areas report they use). That causes a divergence of information and prices out of reality, so we have to eliminate those atypical elements meanwhile the hospital polish their registers.

4 Conclusions

Through this work were identified some Mexican healthcare system needs. So, a first step to transform the actual circumstances is to be clear on the amount of money the institutions will need to operate normally and detect opportunity areas more efficiently. In addition, our solution approach raises awareness of physicians in how the resources are consumed, provoking a better use and attempts to optimize their consumption. To tactical groups emerge ideas of restructuring their processes for delivering a better service, generated when the entire context spectrum is showed. Finally, we can highlight the benefits of cost estimate systematization since it gives a preamble to standardize activities and makes internal transactions more transparent also, this is a tool to the strategic sphere with which they can make better long-term decisions.

The system constructed was made to self-manage if the hospital decides to implement it to the rest departments and intended to be as easy as possible for principal users, physicians who are non-experts on software development. At first, we noticed natural resistance in adopting this new approach from the hospital's staff. But through the project, people were increasingly interested in final results, provoking a better response from clinical areas and obtaining reliable data due to their cooperation. For that reason, we think these are the initial steps of an evolving system that could be functional not just for Gea González Hospital but the entire network of 2nd and 3rd level healthcare institutions that grants a smooth and constant information flow in favor of our final users who deserve an incessant search of new ways to offer a better service, the patients of the Mexican healthcare system.

4.1 Future Work

As we mentioned, this is a preamble in search of strengthening and refining the interface constructed. In that way, some proposals could be interesting to implement in new future projects. At first, database and system logic were established on the Microsoft environment, manly Excel and Access, but during the project, the hospital was managing the purchase of MySQL licenses, so it is advisable to export all data to that platform, even more, if they are planning to scale the system to all the hospital. Likewise, we don't have to forget to make a periodical revision about the resource validity because they change constantly. For that reason, it's necessary to automate or improve the way the system process these transactions. On the other hand, we recommend a deeper analysis for processes and their relations between clinical areas, because in that way we can define clearly the critical patient paths of their attention cycle and optimize resources allocation. A dedicated team to this system could enhance it by giving it maintenance and improving the process mapping in terms of resource and time consumed in each process. At the end, this should be a task that needs to detonate a new accountability and control culture in which every stakeholder in the hospital should align their data management to this system so it can be enhanced to its maximum potential. Finally, this is an always-changing ecosystem, so the computerized costs program has to update its data until reaching a higher degree of convergence with actual hospital behavior and obtain trustworthy information that allows an excellent sustainable performance.

Acknowledgements. We thank to CIMA (Applied Medical Innovation Center) department at General Hospital "Dr. Manuel Gea González", specially to Edna Rangel who greatly supported the development of this project and to Miguel Gorostieta who helped us obtaining the hospital information from managers and directors. Also, we thank UNAM (Autonomous Mexico's National University) and its PAPIIT program IA105220 "Optimización en Logística Hospitalaria" for support and make possible the project.

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