ISSN 1870-4069

Design of a Data Repository for Analysis of Inventory in the Mexican Healthcare System by Means of Data Analytics: Case of Study of a Clinic in the Southeast of Mexico

José Alberto Hernández Aguilar[1], Mariana Ugarte Nava[2],
Julio César Ponce Gallegos[2]

[1] Universidad Autónoma del Estado de Morelos,
Mexico

[2] Universidad Autónoma de Aguascalientes,
Mexico

jose_hernandez@uaem.mx

Abstract. We discussed a data warehouse designed for the health Mexican sector to maintain a proper inventory of the clinics, avoiding as much as possible the misuse of medicines and supplements, for this purpose, we analyzed the characteristics of the main data repositories and their characteristics, later we focus on creating a proposal to support the Mexican health care system oriented on the optimal management of inventories. Our preliminary results indicate that it is possible to maintain adequate inventories of items (medicines and supplements) that are deemed critical from the refill with inventory techniques.

Keywords: Data warehouse, healthcare system, inventory, two-bin system.

1 Introduction

The companies that are suppliers of entities in the area of health care need to maximize the benefits of their delivery operations of inputs. For their part, the health sector entities, both public and private, face several challenges in the management of material resources, as the vast majority has major shortcomings with regard to the visibility and updating of the inventory of inputs, processes of patient care, in addition to that have complex structures of payment to suppliers, among other problems. To cope with these challenges, this obliges them to give special importance to logistic systems, especially where the clinician has to manage inventories. The steps that need to be done manually make the processes more prone to errors, slow, and therefore, expensive.

An approach to solve this situation is supported by Information Technology (IT), where databases are key elements in applications that manage supplies, and there are lot of applications related to the health sector.

Table 1. Features identified for treatment of patients based on [3, 4].

<<Treatment>>
1. Type of case
2. Type of department
3. Patient Type
4. Type of partial payment
5. Number of days of medication
6. Gender of the doctor
7. Cost of the medication
8. Cost of diagnosis
9. Cost of the review
10. Cost of medication administration.

In the real world, you can find very complete database systems, as the American Health Care System, the health system in Singapore and in the case of Latin America excels that of Brazil. According to the literature [1] and the reality observed, data bases of the health sector are usually very large and contain many tables and information, for example, the Brazilian Health Sector system requires 380 tables to operate. In addition to this, the information can be difficult to access, and in several Mexican institutions, information derived from day-to-day operations is not digitized or even stored in electronic media without any normalization process. According to [2] that is why we will see this research from the point of view of data analytics.

2 Related Work

For the design of the data repository literature was reviewed with the aim to identify the most frequent operations of health institutions, for this purpose were reviewed several works, among whose was considered those that discuss the treatment for patients, the operation of the clinical laboratory, the emergency area, the management of the inventory of medicine, and the use of drugs and supplies.

Treatment for patients. In [3], several data model for getting clinical effectiveness are discussed and how *the treatment* given to a patient over a period of time is modeled with a table. This requires a folio number, the department, the patient type, and type of payment, the number of days of medication, the gender of the doctor, the cost of the medicine, the cost of diagnosis, the cost of revision and the cost of medication administration, see Table 1.

It may be inferred from the above table that there is a need for additional tables with the data in the event, the patient, the Doctor, Medicines and billing.

These elements are fundamental for the control of the costs of patient care. It should be noted that these fields are part of the database of Medicare in the United States of America, which is considered as big data [5].

Operation of the clinical laboratory. Another fundamental element in the operation of health institutions corresponds to the operation of the clinical laboratory. In [6] is proposed a star schema, at the center of this star is the table of the results of the clinical laboratory with primary key (IDResult), which connects with other entities from foreign keys (Fk- Foreign key), in which the patient ID (IDPatient), the id of the Doctor (IDPhys), for the control of the test the Id of the test (IDTest), to locate the test in the IDTime) and time (for the control of facilities (IDLocation). The entities involved are patient, doctor, laboratory test, time, location, all of which are linked to the output table of the Clinical Laboratory.

Operation of the emergency area. The operation of the emergency room mix some of the entities described above in a massive form [7], namely laboratory testing and treatment however includes the entities: radiological examination, Evolution of the exam, Episode, monitoring and diagnosis, all of them including the temporality (timestamp) on each one.

Inventory of medicine. The inventory of the medicine and particularly high-value of the drug was modeled by [8] cited in [9], it proposes a very simple form for the control of stocks and of the possible deviations in the same:

Amount stolen = (Stocks at the start of the day - Stocks at the start of the next day) - Medicine Prescription Assortment (1).

Therefore, if at the start of the day had 100 pieces of a medicine, and the next day there are only 90 pieces, but only took 7 pieces, there would be a shortfall of 3 pieces:

Stolen Inventory = (90) - 100 - 7 = 10 -7 =3.

It follows the detail of the recipe, which can be used to calculate the cost of medicines. It should be noted that it would be required to associate this information with the Doctor and Patient. To identify who issued the treatment to and to who was ad ministered.

The scheme described in Table 2 can be adapted for the management of supplies to health institutions, for example: syringes, gauze, etc. as well as equipment.

Considering the above discussed, the repository design is shown in figure 1 as entity relationship diagram. This schema concentrates the management of supplies of drugs, equipment, and others. It shows the entities involved and events that can occur in the day-to-day operations of a health institution, which is modeled on what has been called IDEvent in the Events table. In each event is given appointment the doctor, patient, and if necessary the use of laboratory tests, as well as the results, that trigger in treatment, which may require one or more prescriptions which in turn impacts the inventory level.

Table 2. Entities required for inventory control of medicines, based on [9].

<<Medicine>>
IdMedicine
Name
Presentation
Existence
Price
Time Stamp
<<Prescription>>
IdPresciption
IdDoctor
IdPatient
Date
IdMedicine(s)

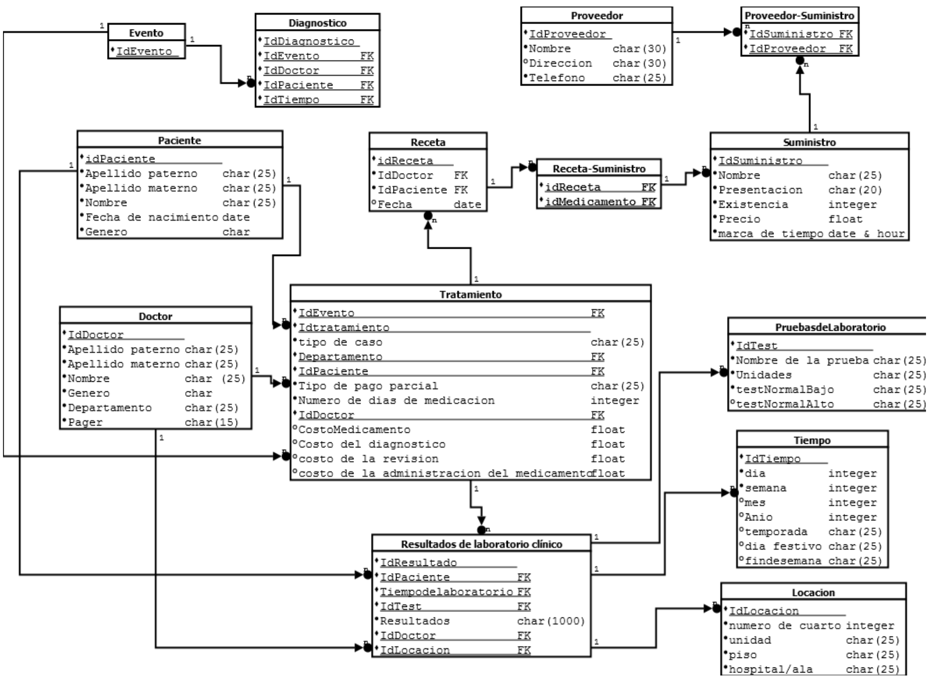


Fig. 1. Proposed Data Repository.

It should be noted that in this design particular care in handling of the spaces, of the costs of services, as well as of the times in which the processes are carried out. We will focus in the inventory management.

According to [10], the inventory is defined as "all the money that the system invests in the purchase of things the system aims to sell", if we apply this concept to the health sector and what we modify slightly would be something like: "All the money the health sector invests in the purchase of medicines and supplies that the system uses to deliver health quality services."

In this sense, of the inventory conceived as a resource indicating that [11]: "The inventory is any stored resource that serves to satisfy any need now or in the future", these authors indicant that all organizations have some system of Planning and control of inventory, in this way a bank has methods to control your inventory of cash, a hospital has methods for controlling the bank of blood and other important inputs.

3 Methodology

For this investigation, the method of study case will be used to analyze the inventory of a health clinic in the southeast of Mexico using data analytics, the case study method is a methodological tool that can be applied in any area of knowledge and allows quantitative and qualitative methodologies to be used [12].

The purpose of all models and techniques used on inventories is to determine in a rational way how much and when to order [11]. For this research we used the model of inventory for cost reduction in the real world described by [11] and adapted from [13], which consists of the following stages:

1. Definition of the problem.
2. Development of the model.
3. Data collection.
4. Development of a solution.
5. Evidence of the solution.
6. Analysis of the results.
7. Implementation of the results.

Definition of the Problem. How to reduce missing medicines and supplies for a health care clinic in the southeastern of Mexico using data analytics.

Development of the Model. The figure 2 shows the proposed model. The first stage determines what to purchase and store for the inventory. In the second stage is carried out the demand forecast for inventory, and the third stage is controlled the process. A feedback loop allows adjusting the plan and the projection from the experience and observation [11]. For a better control is proposed the use of a Two-bin Kan-Ban system (see Figure 2).

Data Collection. For proof of the use of medicines and supplies, information was provided from operations of a health clinic of the Mexican Southeast, with information from the period from January to September 2016. The fill format is displayed in the following figure.

As can be seen in the previous figure, the inventory control is done manually; these control sheets were captured and preprocessed in Excel. Highlighting the Elements Date, Area, Quantity, Material requested, Stocks, Name, Existence and Observations (see figure 4).

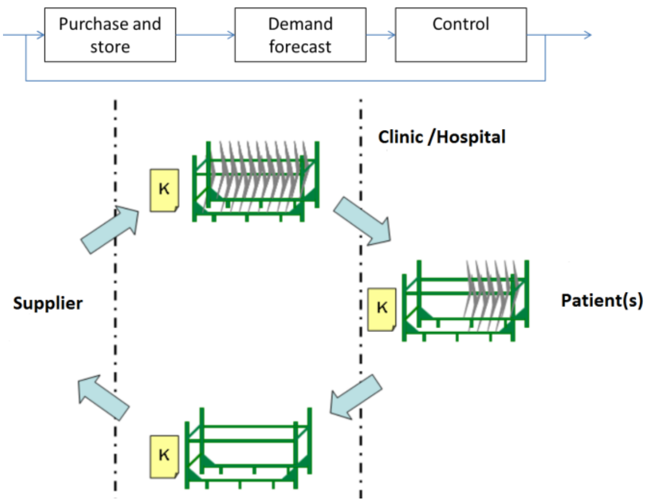
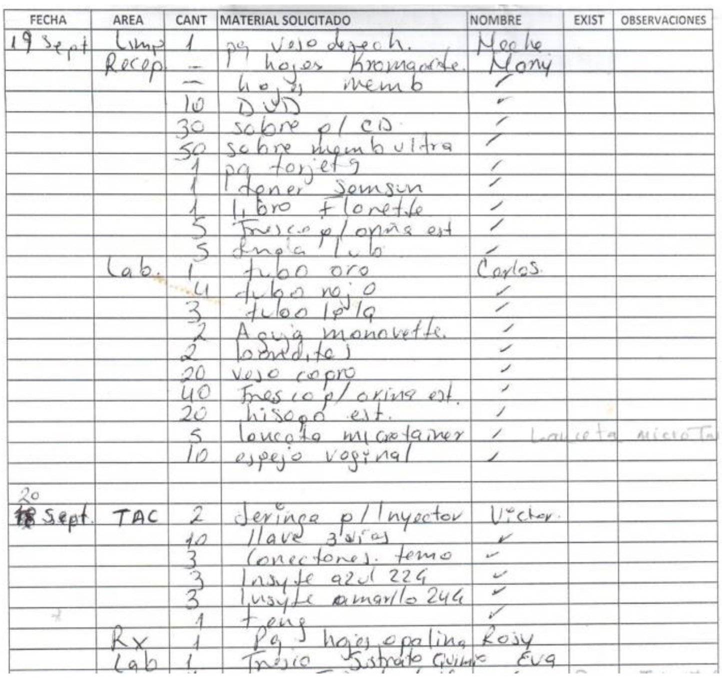


Fig. 2. System of planning and inventory control [11].



FECHA	AREA	CANT	MATERIAL SOLICITADO	NOMBRE	EXIST	OBSERVACIONES
19 Sept	Limp	1	pq vaso desech.	Meche		
	Recep	–	pq hojas Kromacote	Mony		
		–	hojas memb	✓		
		10	DVD	✓		
		30	sobre p/ CD	✓		
		50	sobre memb ultra	✓		
		1	pq tarjetas	✓		
		1	toner Samsung	✓		
		1	libro florete	✓		
		5	frasco p/ orina est	✓		
		5	[illegible] lab	✓		
	Lab.	1	tubo oro	Carlos		
		4	tubo rojo	✓		
		3	tubo lila	✓		
		2	Aguja monovette	✓		
		2	[illegible]	✓		
		20	vaso copro	✓		
		40	frasco p/ orina est.	✓		
		20	hisopo est.	✓		
		5	lanceta microtainer	✓	Lanceta	micro Ta
		10	espejo vaginal	✓		
20 Sept	TAC	2	Jeringa p/ Inyector	Víctor		
		10	llave 3 vías	✓		
		3	conectores. femo	✓		
		3	Insyte azul 22G	✓		
		3	Insyte amarillo 24G	✓		
		1	[illegible]	✓		
	Rx	1	pq hojas opalina	Rosy		
	Lab	1	frasco sustrato [illegible]	Eva		

Fig. 3. Detail of Control Sheets of medicines and supplies in a clinic in the health sector.

As can be seen, the previous table database can be used to calculate the deviations in the management of the inventory as it has the field inventories. However, this information is not provided.

FECHA	ÁREA	CANTIDA	MATERIAL SOLICITADO	NOMBRE	EXI	OBSERVACIONE
19-sep	Limp	1	Paquete vaso desechable	Meche		
19-sep	Recep	1	Hojas kromacote	Mony		
19-sep	Recep	1	Hojas membretadas	Mony		
19-sep	Recep	10	DVD	Mony		
19-sep	Recep	30	Sobre para CD	Mony		
19-sep	Recep	50	Sobre memb ultra	Mony		
19-sep	Recep	1	Paquete tarjetas	Mony		
19-sep	Recep	1	Toner samsung	Mony		
19-sep	Recep	1	Libro Florette	Mony		
19-sep	Recep	5	Frasco para orina est	Mony		
19-sep	Recep	5	Funda lub	Mony		
19-sep	Lab	1	Tubo oro	Carlos		
19-sep	Lab	4	Tubo rojo	Carlos		
19-sep	Lab	3	Tubo lila	Carlos		
19-sep	Lab	2	Aguja monovette	Carlos		
19-sep	Lab	2	Banditas	Carlos		
19-sep	Lab	20	Vaso copro	Carlos		
19-sep	Lab	40	Frasco para orina est	Carlos		
19-sep	Lab	20	Hisopo est	Carlos		
19-sep	Lab	5	Lanceta microtainer	Carlos		
19-sep	Lab	10	Espejo vaginal	Carlos		
20-sep	TAC	2	Jeringa para inyectar	Victor		
20-sep	TAC	10	Llave 3 vias	Victor		
20-sep	TAC	3	Conectores temo	Victor		

Fig. 4. Detail of Control Sheets of medicines and supplies in southeast clinic (own source).

Table 3. Measures of the Theft in Public Hospitals in Venezuela [9] based on surveys to the Staff.

Concept	Percentage of Staff that indicates that the theft occurs	Stolen percentage (%)
Surgical Supplements	67.0	10.1
Medications	64.4	13.4
Computer	50.1.	5.7
Food	42.3	12.2
Other	28.2	3.4

Statistical Analysis. In [14] was used univariate logistic regression analysis to identify the association between supply change management and the audit variables for a review of POC (Point of Care) diagnostics in 100 Clinics in Ghana, based on this analysis they identified similar problematics to those experienced in the Clinic of southeast of Mexico like high clinic attendance, poor documentation of inventory level, and poor monitoring of monthly consumption level. For this study we used two variables: the quantity of material requested and the date to model the usage of medicines and supplies during a period of time, by using of time series which works in linear data to make forecasting [15, 16].

Development of a solution. According to [17] cited in [9] the level of missing in public hospitals round the 10% on average, varies according to the type of article, as well as surgical supplements have a 10.1% of missing, medicines the 13.4%, the team 5.7%, the food 12.2% and other 3.4%, see table 3.

3.1 Algorithm for the Optimization of Critical Items (Supplies and Medicines)

By what was previously described, in order to optimize the items critical to the operation of health institutions intends to use the methodology developed by [18], which consists of 4 stages:

1. Identify the critical items through an ABC classification, which considers factors such as costs and inventory turns, so that they selected the items they need a policy of inventory.
2. Analysis of the behavior of the demand of the items to identify the existence of patterns. At this stage, we identified the demand of the item in order to identify the most appropriate form of their prognosis, and thus be able to estimate their behavior.
3. The parameters of the inventory policy according to the results of the previous stages.
4. Inventory policies evaluation. For health institutions is proposed the implementation of a policy of continuous review (s, Q).Where s represents reordering point and Q represents a product request of a fixed size Q. Each time you reach the states, system generates an order with the amount Q. This policy is also known as "Two-bin system", this system consists of two Kan-Ban systems in tandem and has been shown to give excellent results in public health institutions [19] and exemplified at St Clair Hospital in https://www.youtube.com/watch?v=yjSwwPF5BUU.

This could be achieved according to the following formulas:

$$EOQ = \sqrt{\frac{2AD}{v\,r}}. \tag{2}$$

The Equation 2 represents the optimal amount of order, expressed in units, where:

Fixed cost of placing an order in monetary value.
D- Annual Demand,
v- Value,
r- ratio,
v*r - Inventory Management Cost as a percentage of the value of the product, in annual percentage rate:

$$ROP = d*t. \tag{3}$$

The Equation 3. Allows you to calculate the refill point, where:

D is the demand in units/day,
T is the waiting time known (days).

Evidence of the solution. Next, we show the performance of the proposed policies by means of simulation in worksheet of the selected products.

In the database of the Clinic under study, we identified critical items that need a policy of inventory, some examples are: sealed envelopes, letterhead sheet, urine bottle,

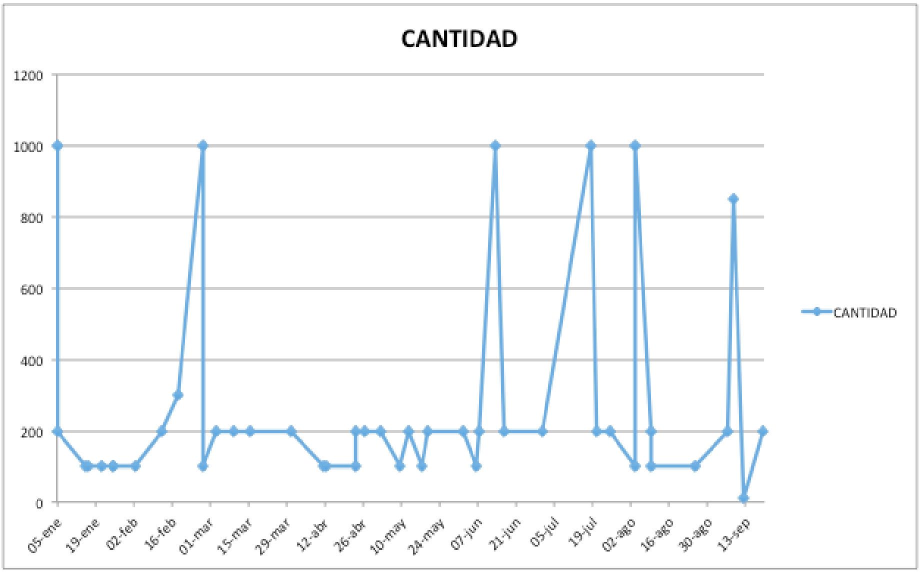


Fig. 4. Identification of critical items in the Clinic of Chiapas, the figure shows the consumption of sealed envelopes.

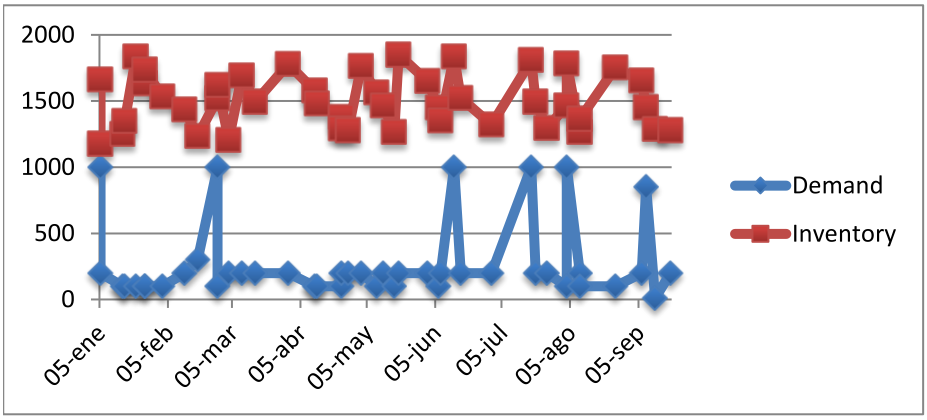


Fig. 5. Simulation of item on letterhead sheet stationery.

copro cup, yellow tips, speculum, tongue depressors, among others. Analysis and implementation of the results will be discussed in next section.

4 Results and Discussion

We proceeded to analyze the behavior of the demand. Table 4 shows the actual demand (January to September) of some critical items.

1. The parameters passed to inventory policy. To do this we tested a value of 100, a cost of inventory management 5% annual and a "fixed" refill (ROP) of 10%. With

Table 4. Identification of critical items.

No. Article	Critical items (high consumption)	Units	Cost	Unit cost*
1	On the letterhead stationery	11760	3.5	41160
2	Letterhead Sheet	21728	1.5	32592
3	Copro cup	1630	4	6520
4	urine bottle	4949	4.3	21280.7
5	Yellow Tips	5899	0.4	2359.6
6	Speculum	341	5	1705
7	Tongue depressors	1886	1	1886

Table 5. Policy parameters of inventory, resources (own and mercadolibre.com).

No. Artic	Critical items (high consume)	Refill point S	Quantity Q
1	On the letterhead stationery	1176	686
2	Letterhead Sheet	2172.8	932
3	Glass Copro	163	255
4	For urine bottle	494.9	445
5	Yellow Tips	589.9	486
6	Speculum	34.1	117
7	Tongue depressors	188.6	275

these parameters are calculated the optimum amount of order for critical items under discussion.

2. The parameters passed to inventory policy. To do this we tested a value of 100, a cost of inventory management 5% annual and a "fixed" refill (ROP) of 10%. With these parameters are calculated the optimum amount of order for critical items under discussion.

3. We evaluated the performance of the proposed policies, in the following figure simulation for the item on letterhead stationery, considering the refill point 1176 and an order quantity Q of 686 units.

As can be seen in the simulation, the proposed model ensures that the item is in stock at all times during the operations of the institution of health, that is why it is vital to analyze the behavior of each item and its peak demand periods in time.

5 Conclusions and Future Work

A Data repository to analyze inventory in the Mexican Healthcare system was designed, we proposed the use of data analytics due the high quantity and potential of information managed in this type of systems.

We proposed a two-bin Kan-ban system to control inventory and reduce missing supplies and medicines for a health care clinic in the southeastern of Mexico. We demonstrate is possible to use single data analytics to achieve that goal.

This work is be not means completed, our future work will focus on the use of data analytics mentioned in [20] for Mexican health care institutions.

References

1. Schneeweiss, S., Avorn, J.: A review of uses of health care utilization databases for epidemiologic research on therapeutics. Journal of Clinical Epidemiology, 58, pp. 323–337 (2005)
2. Raghupathi, W., Raghupathi, V.: Big data analytics in healthcare: Promise and potential. Health Information Science and Systems, 2 (2014)
3. Kahn, M.G., Batson, D., Schilling, L.M.: Data model considerations for clinical effectiveness researchers. MedCare, 50 (2012)
4. Deshpande, A.M., Brandt, C., Nadkarni, P.M.: Temporal query of attribute-value patient data: Utilizing the constraints of clinical studies. International Journal of Medical Informatics, 70, pp. 59–77 (2003)
5. Medeiros, B.C., Satram-Hoang, S., Hurst, D., Hoang, K.Q., Momin, F., Reyes, C.: Big data analysis of treatment patterns and outcomes among elderly acute myeloid leukemia patients in the United States. Annals of Hematology, 94, pp. 1127–1138 (2015)
6. Lyman, J.A., Scully, K., Harrison, J.H.: The development of health care data warehouses to support data mining. Clinics in Laboratory Medicine, 28(1), pp. 55–71 (2008)
7. Lin, W.T., Wu, Y.C., Zheng, J.S., Chen, M.Y.: Analysis by data mining in the emergency medicine triage database at a Taiwanese regional hospital. Expert Systems with Applications, 38, pp. 11078–11084 (2011)
8. La Forgia, G., Cross, H.: Health financing and management in belize: An assessment for policymakers. A Compendium of Technical Notes, Cost Recovery, 2 (2001).
9. Di Tella, R., Savedoff, W.D.: Diagnosis corruption: Fraud in latin america's public hospitals. Harvard Business School, Faculty & Research (2001)
10. Goldratt, E.M., Gibler, N.A.: El sindrome del pajar: Cómo extraer información del océano de datos. Ediciones Castillo (1999)
11. Render, B., Stair, R.M., Hanna, M.E., Hale, T.S.: Quantitative analysis for management. Pearson (2012)

12. Cristina, P., Carazo, M.: El método de estudio de caso Estrategia metodológica de la investigación científica. Pensam Gestión, pp. 165–193 (2006)
13. Lee, H.L., Billington, C.: The evolution of supply-chain-management models and practice at hewlett-packard. Interfaces (Providence), 25, pp. 42–63 (1995)
14. Kuupiel, D., Tlou, B., Bawontuo, V., Drain, P.K., Mashamba-Thompson, T.P.: Poor supply chain management and stock-outs of point-of-care diagnostic tests in Upper East Region's primary healthcare clinics, Ghana. PLoS One, 14 (2019)
15. Olson, D.L., Wu, D.: Predictive data mining models. Springer (2020)
16. Madrigal-Espinoza, S.D.: Modelos de regresión para el pronóstico de series temporales con estacionalidad creciente. Computación y Sistemas, 18, pp. 821–831 (2015)
17. Jaén, M.H., Paravisini, D.: Diseño institucional, estructura de incentivos y corrupción en hospitales públicos en Venezuela. RePEc (1999)
18. Aguirre-Lasprilla, S.: Parametrización y evaluación de política de inventario (s,Q) en hospitales: Un caso de estudio en la ciudad de Barranquilla. Prospectiva, 13, pp. 99 (2015)
19. Graban, M.: Lean hospitals: Improving quality, patient safety, and employee engagement. CRC Press (2018)
20. Raghupathi, W., Raghupathi, V.: Big data analytics in healthcare: Promise and potential. Health Information Science and Systems (2014)