COMPUTATIONAL INTELLIGENT METHODS AND TOOLS TO IMPROVE THE TECHNICAL PLATEAU MANAGEMENT OF A HOSPITAL

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Abstract: *The study aims at analyzing the methods for resource allocation with a view to streamline the hospital technical plateau and its sustainable development. In a hospital, data represent an essential source for the production of short and medium-term strategies for controlling costs and improving the quality of health services. These strategies lay at the basis of improving hospital management, thus requiring the use of intelligent methods and tools for storing, processing, filtering, and obtaining information from these data. Strategies to achieve the extraction of knowledge require: the descriptive, exploratory stage and the inferential, confirmatory stage. Computational intelligent methods and tools for data analysis are those univariate and multivariable.*

Cuvinte cheie: *management administrativ, metode inteligente de calcul, platou tehnic, baza de date*

Rezumat: *Tema îşi propune analiza metodelor de alocare a resurselor pentru eficientizarea platoului tehnic al spitalului şi a dezvoltării durabile a acestuia. Într-o instituţie spitalicească, datele sunt o sursă esenţială pentru elaborarea de strategii pe termen scurt şi mediu privind eficientizarea costurilor şi creşterea calităţii serviciilor medicale. Aceste strategii stau la baza îmbunătăţirii managementului spitalicesc, impunându-se astfel utilizarea de metode și unelte inteligente pentru stocarea, procesarea, filtrarea și obținerea de informații din aceste date. Strategiile de realizare a extragerii de cunoştinţe impun: etapa descriptivă, exploratorie şi etapa inferenţială, confirmatorie. Metodele şi uneltele inteligente de calcul pentru analiza datelor sunt cele univariabile şi cele multivariabile.*

In the work and evolution of an organization, it is imperative to take into account the collected data in order to make informed decision-making. For a hospital institution, these data are a key source for the production of short and medium term strategies on cost efficiency and quality of medical services. These strategies will be the key to improve hospital management. In recent years, for more and more organizations, data collection became a normal phenomenon. As the volume and complexity of data are constantly increasing, it is necessary to use intelligent methods and tools for storing, processing, filtering and obtaining information from these data.

Extracting information / learning from data

Extracting information / learning from the data / discovering new knowledge are the primary goal of intelligent computational methods and tools. Learning from data can be done in a supervised or unsupervised manner. Supervised learning objective is to predict the value of the output data based on the input data, while in the case of unsupervised learning, there is no output data, the final aim being to describe the associations/characteristics of the input data.

The learning process is based on methods and techniques from several fields: statistics, databases, machine learning, neural networks, artificial intelligence. The concepts of regression, clustering, classification, correlation, distribution, median, combinations of models are currently used by new technologies, representing the foundations of modern learning algorithms.

Strategies to achieve the extraction of knowledge

Descriptive and exploratory stage

A first step in extracting data consists of data exploration. This first descriptive and exploratory stage analyzes elements such as distribution form, identification of atypical values, any data transformations required by the distribution form or data standardization, mean, dispersion, variation, correlations, classifications etc. This approach results in achieving a description of data sets, namely the establishment of relationships between variables, thus providing a first general idea of the data.

In this stage, two main objectives can be considered. The first objective consists of the uni and multidimenional exploration or the reduction of the size, while the methods, or tools used are: factor analysis, principal component analysis, analysis of simple correspondences. These methods consist of analyzing a cloud of weighted points in a metric space with special cloud shape characterizing the nature and intensity of the relationships between variables and revealing information contained in data structures. The second objective is the classification or segmentation, with the following methods: hierarchical ascending classification (progressive cluttering of elements), the k-means (interactive aggregation of elements around the mobile centres) or mixed methods. In this case, division is desired, that is the distribution per classes or categories by optimizing a criterion, each class having the property that is as homogeneous in relation to its elements and as distinctive compared to other classes.

Inferential and confirmatory stage

The first stage is preceded by a second stage, the inferential one. This step uses the results obtained in the first step as a statistical hypotheses testing or probabilistic models to explain, that is to provide a particular variable by means of one or more of the explanatory variables. The main objective in this stage is modelling, respectively deducing a predictive model. To

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achieve this, we can use methods such as linear regression, ANOVA, ANCOVA, neural networks, classification and regression trees, SVM, ie models based on statistical observations series: spectral analysis, seasonality analysis.

Data base

Considering the fact that currently, there is no national study on the costs of hospital indicating the financing need, the hospital system suppliers have not developed an offer of documented care packages to help donors and patients purchase the services; the hospitals cannot accurately calculate the costs of each medical service required by the quality standards; the management must be adapted to reality and the managers involved in the decision making process for the allocation of funds should perform a database.

In this paper, we used the database necessary to a hospital management. The role of hospital maintenance was always relative, but by careful monitoring of consumption, maintenance is intuitive and can be planned and scheduled in a sustainable strategic management. This has the advantage that maintenance can be planned and budgeted instead be considered only when it becomes absolutely necessary. Such practices often result in delaying or ignoring maintenance.

In order to improve the public hospital management, it is recommended to estimate consumption and implicitly the costs per patient and per day of hospitalization not only medically but also in terms of maintenance and operating costs (administrative technical plateau expenses), through a set of a indicators to complement the current range of management indicators. In this context, within the database, a first set of data is represented by the consumption indicators, necessary to the technical plateau management of a hospital, namely: hospitalization costs, hospitalization costs / patient and / bed and hospitalization costs / day of hospitalization. Thus, the following indicators have been monitored within the database: energy consumption, energy consumption / patient, energy consumption / day of hospitalization, gas consumption, gas consumption / patient, consumption of gas / day of hospitalization, water consumption, water consumption / patient, water consumption / day of hospitalization.

A second set of indicators is represented by the repairing and investment indicators, also necessary to the management of the technical plateau, such as: current repairing and building investments, equipment investments

A third set of data consists in the hospital performance indicators that reflect the quality of medical care and efficiency in economic terms: number of cases resolved through continuous hospitalization and through one-day hospital - total of discharges, disease complexity index, average length of stay, utilization level of beds.

The intelligent computational methods and tools used on such data aim at: analyzing consumer indicators trend, trend analysis of repairs and investments in buildings indicators, trend analysis of performance indicators, analyzing the relationship between the indicators of consumption and the investments and repairs indicators and analysing the link of total income and consumption indicators, i.e. repairs and investment indicators, estimating and predicting the values of consumption, performance indicators.

Intelligent computational methods and tools for data analysis

The data series used in the analysis are time series covering the period 2000-2012, during which the indicators necessary to the technical plateau management of a hospital were monitored. The software used for data processing and statistical analysis was SPSS 19. A time series / chronological series is a sequence of observations of a variable Y, ordered by time parameter being represented in the form:

$$Y : \begin{pmatrix} 1 & 2 & \dots t \dots & T \\ Y_1 & Y_2 & \dots Y_t \dots & Y_T \end{pmatrix}$$

Time series analysis aims at understanding, modelling the mechanism of generating the series terms, the model obtained being then useful for generating predictions, prediction being an inference of a variable outside the observed period of time. Prevision can be achieved using: univariate models, which are appropriate when the estimated value is considered according to the evolution accomplished by the variable in the past, without taking into account the influence of other explanatory variables:

$$Y_t = f\left(Y_{t-1}, Y_{t-2}, \cdots, Y_{t-p}, \varepsilon_t\right)$$

and multivariable models, these rendering both the evolution of the variable to predict and of the other variables that explain its behaviour.

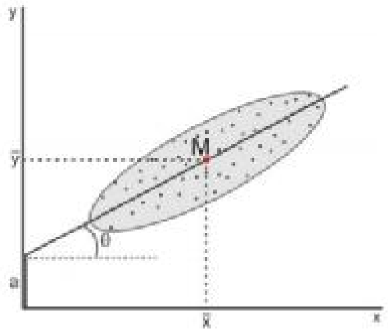
For modelling and predicting the tendency, the elementary functions slowly varying in time are taken into account, of which:

Table no. 1. **Elementary functions of modelling and predicting**

Elementary functions	**Tendency**
linear	$y = a + b*x$
parabola	$y = a + b*x + c * x^2$
hyperbola	$y = a + b/x$
exponential	$y = a * b^x$
power	$y = a * x^b$

In the above functions, the role of exogenous (independent) variable is played by the variable “time”, and in terms of geometry, parameters of the regression “a” is the distance from the origin of the coordinates system to the point of intersection of the ordinate with the regression right, and the “b” regression parameter represents the slope of the regression line $b=tg(\theta)$. In the case in which the parameter “b” is positive, we say that the series have a tendency to increase, and when this parameter is negative, the series has a tendency to decrease. The figure below is a graphical interpretation of the regression parameters.

Figure no. 1. Graphical interpretation of the regression parameters



Source: silvic.usv.ro/cursuri/biostatistica.pdf

To estimate the parameters of the linear regression equation, the most used method is the method of least squares, according to which the formulae for the calculation of the parameters “a” and “b” are the following:

Table no. 2. Calculation formulae for the parameters of the linear regression equation

$b = \dfrac{n\Sigma tY - (\Sigma Y)(\Sigma t)}{n\Sigma t^2 - (\Sigma t)^2}$ $a = \dfrac{\Sigma Y}{n} - b\left(\dfrac{\Sigma t}{n}\right)$	or equivalent	$b = \dfrac{M(tY) - M(t)M(Y)}{M(t^2) - [M(t)]^2}$ $a = \overline{Y} - b\overline{t}$.

Results

Testing the hypothesis of normal distribution of data sets was performed using the "One-Sample Kolmogorov - Smirnov Test", obtaining for all indicators, a coefficient significance p> 0.05, indicating the normal distribution of the data series.

Table no. 3. One-Sample Kolmogorov – Smirnov Test

One-Sample Kolmogorov-Smirnov Test

		consum energie	consum en. /pacient	consum en./zi de spitalizare	consum gaz	consum gaz/pacient	consum gaz/zi de spitalizare	consum apa	consum apa/pacient	consum apa/zi de spitalizare
N		12	12	12	12	12	12	12	12	12
Normal Parameters[a,b]	Mean	380156,58	32,4533	7,2075	144500,42	13,9633	2,9983	17131,83	1,5950	,3167
	Std. Deviation	37398,196	11,25446	1,00341	26031,832	6,84428	,50648	4126,396	,90689	,07215
Most Extreme Differences	Absolute	,242	,220	,206	,266	,255	,142	,199	,172	,130
	Positive	,116	,220	,206	,266	,255	,142	,136	,169	,117
	Negative	-,242	-,154	-,131	-,176	-,200	-,087	-,199	-,172	-,130
Kolmogorov-Smirnov Z		,837	,761	,714	,922	,883	,493	,689	,597	,450
Asymp. Sig. (2-tailed)		,485	,608	,687	,363	,416	,968	,729	,868	,987

The calculation of the correlation coefficient was used to study the direction, form and intensity of the relationship between the variability series of the data: indicators of consumption and investments and repairs indicators or the performance indicators.

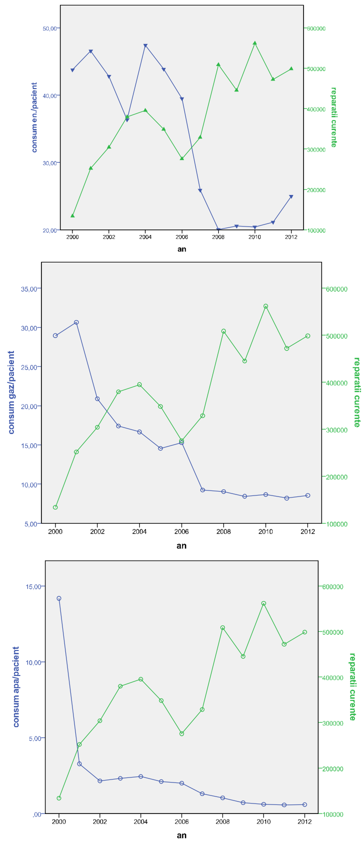
Table no. 4. Correlation coefficient between indicators

		consum en. /pacient	consum en./zi de spitalizare	consum gaz/pacient	consum gaz/zi de spitalizare	consum apa/pacient	consum apa/zi de spitalizare	durata medie de spitalizare totala	indice de complexitate boala	reparatii curente
consum en./pacient	Pearson Correlation	1	-,429	,824**	,170	,486	,363	,793**	-,943**	-,763**
	Sig. (2-tailed)		,143	,001	,578	,092	,223	,001	,000	,002
	N	13	13	13	13	13	13	13	8	13
consum en./zi de spitalizare	Pearson Correlation	-,429	1	-,459	,115	-,126	-,049	-,636*	,555	,447
	Sig. (2-tailed)	,143		,115	,708	,681	,873	,019	,153	,126
	N	13	13	13	13	13	13	13	8	13
consum gaz/pacient	Pearson Correlation	,824**	-,459	1	,642*	,709**	,612*	,666*	-,934**	-,831**
	Sig. (2-tailed)	,001	,115		,018	,007	,026	,013	,001	,000
	N	13	13	13	13	13	13	13	8	13
consum gaz/zi de spitalizare	Pearson Correlation	,170	,115	,642*	1	,721**	,727**	-,002	,886**	-,419
	Sig. (2-tailed)	,578	,708	,018		,005	,005	,994	,003	,154
	N	13	13	13	13	13	13	13	8	13
consum apa/pacient	Pearson Correlation	,486	-,126	,709**	,721**	1	,990**	,351	-,968**	-,746**
	Sig. (2-tailed)	,092	,681	,007	,005		,000	,240	,000	,003
	N	13	13	13	13	13	13	13	8	13
consum apa/zi de spitalizare	Pearson Correlation	,363	-,049	,612*	,727**	,990**	1	,241	-,733*	-,674*
	Sig. (2-tailed)	,223	,873	,026	,005	,000		,428	,038	,012
	N	13	13	13	13	13	13	13	8	13
durata medie de spitalizare totala	Pearson Correlation	,793**	-,636*	,666*	-,002	,351	,241	1	-,888**	-,743**
	Sig. (2-tailed)	,001	,019	,013	,994	,240	,428		,003	,004
	N	13	13	13	13	13	13	13	8	13
indice de complexitate boala	Pearson Correlation	-,943**	,555	-,934**	,886**	-,968**	-,733*	-,888**	1	,876**
	Sig. (2-tailed)	,000	,153	,001	,003	,000	,038	,003		,004
	N	8	8	8	8	8	8	8	8	8
reparatii curente	Pearson Correlation	-,763**	,447	-,831**	-,419	-,746**	-,674*	-,743**	,876**	1
	Sig. (2-tailed)	,002	,126	,000	,154	,003	,012	,004	,004	
	N	13	13	13	13	13	13	13	8	13

A significant correlation, negative coefficient was observed between energy / patient consumption (r = -0.763, p = 0.002), consumption of gas / patient (r = -0.831, p = 0.000), water consumption / patient (r = -0.746, p = 0.003), average length of stay (r = -0.743, p = 0.004), and the repairs of the building, while a significant, positive correlation was observed between the disease complexity index (r = -0.876, p = 0.004), and the current repairs value.

Following the analysis of data sets using the linear regression method and ARIMA model, the regression coefficient and the regression equations lines was identified, showing the size which an element increases or decreases with when the element which is in relation with increases or decreases by one unit.

Figure no. 2. Relation between the consumption indicators and the repairs indicators



Conclusions:

Using these methods, the hospital management should aim at:

1. Implementing a continuous effort to adapt some international standards and instruments measuring hospital activity in the administrative field.
2. Knowing and describing the current state of funding and equipping the technical plateau, both in terms of the volume of resources and in terms of performances obtained in relation to the resources allocated, monthly and annual consumption analysis of gas, water, electricity, according to the technical equipment at a given time.
3. A new approach of the technical plateau consumptions relative to each discharged patient costs and costs / day of hospitalization and the use of these indicators as a basis for assessing the hospital costs of care.
4. Bringing solutions to improve the administrative management of hospitals, through efficiency of the technical plateau consumptions and reducing the indirect costs of hospital days and thus, decreasing the length of hospitalization of inpatients.
5. The transition from resource-based financing (structures, equipment, personnel etc.) to results-based

financing (treated patients, complexity of diseases treated, no. of patients/physician etc.)

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