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WATER CONSUMPTION MODEL FOR THREE STAR HOTELS IN MAJORCA

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ABSTRACT

The purpose of this article is to develop a method to obtain a mathematical model for monthly water consumption versus occupation, from historical data from hotels, using linear regressions, validated by the square of the Pearson correlation coefficient. Based on data of Majorca hotels with common studied characteristics, current consumption is modeled for each hotel and the group of hotels. Minimum values by intervals of occupation can be obtained from the corresponding optimal models. It is concluded that the methodology displayed for selection of data and hotels, allowed to reach values of the square of the correlation coefficient, higher than 0.89 in the optimal models of the hotels studied.

KEYWORDS

Hotel chain; Economic model; Water consumption; Management.

ECONLIT KEYS

C020; C300; Q250; Q500.

1. INTRODUCTION

The Balearic Islands, with a population of 1,113,114 in 2011, is one of the most important tourist destinations in Europe, with an annual average of 59,821,979 overnight stays and 8,956,065 tourists per year from 2004 to 2011 which involves that water consumptions increase dramatically in summer.

The absence of rivers in these islands where all freshwater inputs for human consumption comes from rainwater reservoirs, rural populations still taken from the roofs, underground wells, imported bottled water by boat from the continent and modern seawater desalination plants, gives us an idea of the importance of controlling water consumption in hospitality from a point of view of environmental sustainability.

This article propounds a reproducible method to obtain a water consumption model of hotel facilities in order to improve their management allowing the manager to meet consumer deviations from his hotel over others with similar characteristics and even predict the effects of using different technologies or saving methods, in the specific case of its establishment or the future consumption of an establishment that is not yet built. So, the objective is to find the method; to do this, monthly water consumption data, of sun and beach, several floors, three star hotels in Majorca, have been collected. The data were obtained through direct requests to the headquarters of various hotel chains and directors of various workplaces of several chains.

With the method developed, different models for each group of hotels that have common characteristics are expected to be obtained. In this case, we are testing the goodness of the method in obtaining the specific model for the group of three-star hotels, sun and beach in Mallorca.

A sample of six hotels and apartment facilities with similar characteristics has been selected. The hotels selected are Roc Linda Hotel, Roc Leo Hotel, Bellevue Belsana Hotel and Apartments, Bellevue Club Apartments, Bellevue Lagomonte Hotel and Bellevue Vistanova Hotel. Total and specific per person and day water consumption data have been collected from 2003 to 2012, period without important building works. These data were taken on a daily basis from the general entry counter of the hotel; therefore data not only relate to tourists staying at the hotel but also include staff usage. Most important ones from a practical standpoint are specific consumption data, as they allow comparison between hotels that have different number of rooms. The total water consumption is denoted by the uppercase letter "A", while the specifics will be denoted by the lowercase letter "a".

This article only considers the consumption for months which the hotel is opened and running, since they are the only ones that make sense from an operational standpoint. The number of months that meet this condition is not the same in all years and in each hotel as they vary depending on the contracting of each year.

The clientele of this group of hotels is clearly segmented into summer and winter markets. In summer, the predominant profile is young, students or couples coming from several European countries, while in winter are retired, mostly Spaniards. Accordingly, the present discussion will consider the influence of seasonal factor in water consumption.

2. BACKGROUND

The need to improve competitiveness in the hotel industry has been widely discussed in the literature. Pulido indicates that before awarding of financing for a hotel project, its technical and financial feasibility is evaluated, as well as compliance with minimum environment standards, although there is no specific financing scheme for this industry. One way to achieve these goals is to reduce variable costs, such as the consumption of supplies, since they influence directly on environmental sustainability.

Thus, there are management computer programs that automate control of staff work at the hotel and streamline the processing of information used in hotel industry. These are programs of Enterprise Resource Planning (ERP) as Navision Financials, Navihotel, Verial or Prestige. An ERP system is a software application that allows the management of all business processes in an integrated company; as defined Chiesa in her hotel business module, these programs provide information about breakdown from different departments, total expenditures in personnel, incidences and materials, reaching even detailed stock control of spare parts that are in the store, which speeds the application of different orders to obtain satisfactory results.

However, management of water consumption is too coarse. ERP only allow the introduction of daily data from water meters and to study monthly consumptions per person. They don't provide a mathematical water consumption model of one hotel, even less for the whole hotel chain.

So there are no methods to rigorously analyse consumption data. There are no models to accurately evaluate the efficiency of a hotel in terms of water consumption, much less models or formulas to evaluate such efficiency for a group of hotels. Everything is based on the insight that comes from the experience of the manager over the years, especially in individual hotels, but also in large chains. This intuition implies assessments that are necessarily imprecise and not entirely objective.

It is remarkable that modelling of energy systems and industrial processes has been widely studied both in the literature as the open loop energy supply models, by Samoulidis; the linear programming model of the American power industry, by Hillsman; models that allow analysis of a single plant from an industry model, by Pilati and Sparrow; energy resource analysis model developed for the U.S. gas industry TERA which utility is described by Limaye and Sharko; the updated revisions of strategic models, such as described by Placket; the dynamic linear programming model of energy resources by Rapoport, or the review paper on energy modelling, by Jebaraj.

Specifically, engineering models (bottom-up) represent an energy system in detail, considered as a set of technologies of production, distribution and final energy demand competing with each other (Hidalgo González). They use a wide variety of mathematical tools. Some of the most relevant are control charts, production and consumption versus time diagrams, production versus consumption graphics, specific consumption versus production graphic, Pareto diagrams, and control systems through technical standardization committee standards. Among all these tools, water consumption versus production, and specific consumption versus production graphics can be extrapolated for the design of an engineering model of water consumption.

With special usefulness for the hotel industry, Monteagudo uses an example of energy consumption versus production in the ice-cream industry, and obtains consumption versus occupation linear graph, but doesn’t filter or segmented data and doesn’t obtain an optimal consumption model.

In his doctoral thesis, Rivero Rodríguez studies a technical project based on cogeneration, by optimizing the thermal and electrical demand curves that integrate hot water services, cold sea water desalination and electricity of a typical hotel. The model includes several equations for energy consumption in most common systems of a hotel; for instance a dishwasher. Nevertheless, the thesis neither gets the empirical curve nor the optimal curve for water consumption in the typical hotel.

Several statistical computer programs are used for data processing; for example, Statistic SPSS program organizes and summarizes information from a sample to generalize empirical data. Molina describes a method for choosing the sample for private consumption, although it is used for hotels as well. The results described are numerical data of percentage of projected savings in relation to the various measures classic generalist water saving.

Saving oriented computer programs are used in hotel industry, sometimes as part of environmental measures, led by the Quality Department and based on SAP BW database. Periodically, these databases extract information on operations performed on the integrated management system, which enable managers’ office to evaluate management, define future scenarios and make decisions. As Meliá hotel chain explains in its Sustainability Report 08. It produces three types of reports: Monthly report for hotel base personnel, Energy consumption report and Comparative average carbon dioxide emission report. None of the three reports provides optimal consumption chain. Thus, the company describes the progress in its annual report 2009, in terms of energy and sustainability, the need for a five-year historical loading their databases, based on the comparing the average cumulative consumption of the years 2007-2009 against the average cumulative consumption values of the years 2004 to 2006, not only to compare similar values of occupation, but also without obtaining a mathematical model.

Cabrera describes a linear regression analysis of energy consumption versus number of rooms occupied which only indicates regression rates, concluding that there are other factors besides the occupation, which influence the consumption hotel facilities, which are the climate, hotel category and type of tourism. This multitude of factors which influence water consumption rates (e.g. seasonality, temperature fluctuations, and variations in visitors over time, changing consumer demand, geographical location, cultural aspects and so forth), means the development of a universal model is practically impossible. However, to address this issue we have focussed on a specific group of hotels, and subsequently present a model applicable to these.

Therefore, given this situation of lack of an objective methodology to study consumption data in hotel industry, as well as mathematical models to objectively analyse normal and optimal water consumption in this industry, this article develops a method that can be applied to different hotel facilities in a segmented way according to their different characteristics, in order to get a mathematical model of normal and optimal consumption for each hotel and for each hotel type. In this regard, Cruz Vicente obtained the tourist water demand curve in Acapulco Hospitality developing a logarithmic model with units number of rooms occupied per litres consumed, depending on other variables also logarithmic, which depends on the total number of rooms per litres consumed and the number of workers per litres. However, it doesn’t calculate optimal water consumption. It doesn’t either take into account the influence of height and other building variables to discern hotel types, but it only groups hotels by location.

Shi-Ming studies the variables that influence water consumption in a city hotel by a multiple regression analysis. The study concludes that laundry loads, number of meals served and occupation influence significantly water consumption, although it doesn’t establish mathematical models of water consumption.

Finally, Assaf uses the metafrontier concept to measure efficiencies between different groups of hotels in terms of environmental and technological variables. The results indicate that the size, ownership, and classification of a particular hotel have a significant impact on its efficiency.

3. GENERAL CHARACTERISTICS OF THE STUDIED TOURIST ESTABLISHMENTS (SAMPLE SELECTION)

Among the multitude of existing hotel establishments, some homogeneous enough to be comparable hotels have been chosen. Studied hotels have similar characteristics: they are sun and sand establishments, their type of construction is the same, their age is similar and they belonged to the same hotel chain: Hotetur. Thus, a particular segment of the hotel industry is well defined. The typical establishment studied is a three star (or three keys) hotel or apartment in Balearic Islands, therefore sun and sand hotel, similar in structure built of reinforced concrete, concrete block and sandstone, belonging to a Spanish hotel chain, and twenty years old at least.

Water facilities of all studied hotels are also similar. They all are registrable by means of utility shafts, with plastic pipes refurbished. Only branches ranging from the local utility shafts are buried, with a water tank for each building or group of buildings, as in the case of Bellevue apartments, with a total of eight water tanks. Leo, Vistanova, BelleVue Club and Lagomonte feature an industrial laundry, but only the ones of Vistanova and Lagomonte work, counting the six centers for washing linens areas.

However, an attempt has been made to the chosen sample to be also different in some characteristics that do not significantly affect the homogeneity of results, because they have little influence on the consumption of water in relation to occupation. Thus, as can be seen in Table 1, not only hotels have been chosen but also aparthotels. The number of building heights studied is different, ranging from five to eight floors. All facilities consist of a single building, except the Belsana, which consists of two complexes and Bellevue, which has eighteen tall buildings. The difference in the number of rooms is much greater, ranging from one hundred of

Belsana to 1,474 of Bellevue. Two other highlights data in Table 1 are the notable differences in garden surfaces, as well as in swimming pool surfaces. This variety of characteristics of the hotels in the sample allows a water consumption model to be representative of the hotel type studied.

	Linda	*Leo*	*Belsana*	*Bellevue Club*	*Vistanova*	*Lagomonte*
Type	Hotel	Hotel	Hotel and apartments	Apartments	Hotel	Hotel
Location (Majorca)	Can Pastilla	Can Pastilla	Porto Colom	Alcudia	Punta Ballena	Alcudia
Hotel chain	Hotetur-Roc	Hotetur-Roc	Hotetur-Bluebay	Hotetur-Bluebay	Hotetur-Bluebay	Hotetur-Bluebay
Stars/Keys	3	3	3	3	3	3
Year of construction	1971	1968	1986	1982	1969	1970
Building type	Several floors	Several floors	Several floors	Several floors	Several floors	Several floors
Number of buildings	1	1	2	18	1	1
Number of floors	5	5	5	8	8	6
Number of rooms	189	285	100	1474	198	272
Number of double rooms	189	275	63	1474	172	245
Personnel rooms	4	0	4	25	0	0
Total capacity pax/month	11,250	18,000	7,500	139,050	12,300	25,500
Garden surface (m^2)	600	200	0	250,000	300	1,600
Specific garden surface (m^2/room)	3.17	0.70	0.00	169.61	1.52	5.88
Swimming pool surface (m^2)	180	350	250	2450	220	450
Specific swimming pool surface (m^2/room)	0.95	1.23	2.50	1.66	1.11	1.65
Spa	No	No	Yes	No	No	No
Distance to beach (m)	250	150	500	800	50	1200
Electronic drive for water pumping	Yes	No	No	No	Yes	No
Pipe type	Reticulated polypropylene (RPP)	RPP	RPP	Iron and RPP	Reticulated polyethylene	Reticulated polyethylene
Air conditioning	Yes	Yes	Yes	No	Yes	Yes
Hot water fuel	Diesel	Natural gas	Propane	Propane	Propane	Diesel
Hot water accumulation volume (m^3)	12	12	10	64	12	18
Working laundry	No	No	No	No	Yes	Yes
Study time range	2003-2008	2003-2008	2003-2012	2003-2012	2003-2012	2003-2012

Table 1: General data of premises.
Source: Own elaboration.

For example, water leakages can be easily controlled in a several floor hotel with registrable utility shafts, except underground pipes in basements and gardens. Plastic pipes existence in buildings sampled indicate that there has been a thorough revamping, since hot and cold water pipes were made only of iron where the studied hotels were built.

Pool surface per room is similar among the studied hotels. The average of this magnitude in the sample is 1.5 m^2 per room. Mention deserves the Belsana, because it has two swimming pools: one for the apartments and another for the hotel. The fact that the complex Belsana has only 100 rooms makes this variable reach 2.5 m^2 per room.

More dispersion is seen in terms of garden surface per room. For example, Belsana doesn't have any garden, only a gravel playground next to Puerto Colom cliff. On the other hand, Bellevue apartments have a great extension of gardens among buildings. In this case, the total area is 169 m^2 of garden per apartment, which includes palm trees and mowed grass areas. The rest of the hotels have similar values of garden specific surface, with an average of 2.81 m^2 of gardens per room.

Presence or absence of laundry does not seem to be highly relevant in these type of hotels, since the Vistanova has a lower consumption in all models studied to Lagomonte, both having laundry. The same has happened with the Belsana SPA.

4. METHODOLOGICAL APPROACH

The functioning of a hotel could be analysed by means of flow sheets that show consumptions in every department. However, this delimitation would be too complex. Data collection would be difficult to perform because of the number of water consuming processes that are interrelated in a hotel and the lack of counting systems necessary for this aim. Usually available hotel water consumption data will be used; namely, daily total water consumption data or at least monthly ones. Consumptions could also be broken down by facilities or concepts. Nevertheless, data gathering would also be too laborious, unless it was limited to a very small number of hotels. Therefore, study will be approached by considering every hotel as a simple system, without dividing it into sub-systems.

Total and specific water consumptions, which will be denoted by uppercase and lowercase “a” letters respectively, are tabulated for each month from the year 2003 to the year 2012, except for hotels Leo and Linda, where the study period only comes to 2008, as shown in Table 1. The specific consumptions will be measured in litres per person per day, while the total ones are measured in litres. Data of the months in which the hotels have been closed and those that show very obvious reading errors have been ruled out.

All these data will be used for several analysis of water consumption versus number of overnight stays and occupancy level by linear regression. Given that there is clear customer segmentation by seasons, all analysis will be performed not only for the full year, but also for the high and low seasons. The first one, known in the hotel industry as "summer" season, covers the months from May to September both inclusive, while the second one, also called "winter", is from October to April.

The data analysis will be divided into two broad categories: water consumption for each hotel and consumption for the hotel group. Both analyses have different objectives and use different mathematical tools. The first one characterizes the water consumption of each hotel, allowing, in principle, to predict or assess their own consumption, and facilitates comparisons between different hotels. The analysis of the second category homogenize and group data from all hotels of the same type, and then find empirical relationships that provide an overview of water consumption in the studied hotel group.

Despite these significant differences, both categories of analysis have two common methodological characteristics. Firstly, both approaches analyse water consumption in the full year as well as in the summer and winter seasons; i.e. they perform not only an annual analysis, but also a seasonal analysis. Secondly, all empirical relations are obtained for both normal and optimal consumptions. The normal consumption analysis includes all consumptions that have passed the aforementioned filters. The optimal consumption will be obtained by taking the minimum rate of water consumption for set occupancy rates, according equal intervals corresponding to an increase of 10% occupancy. The lowest value achievable throughout the year for each interval of occupation is taken. The processing of optimal consumption data will be analogous to its counterpart for normal consumption in each case.

The analysis of the first category will start by checking the apparent linear relationship between monthly water consumption and the number of overnight stays. In this case, the water consumption can be expressed by a straight line as indicated in equation:

$$A = m^{A} \cdot P + A^{F}$$

Equation 1: Monthly water consumption versus overnight stays.

- m^A: slope of the empirical straight obtained for each hotel, which is the average per person water consumption for a specific hotel (L / pax).
- A: gross monthly water consumption (L / month).
- P: number of overnight stays in a month (pax / month).
- A^F: fixed water consumption in one month, independent of individual use (L/month).

Differences between hotels would depend on different consumption rates per person at the individual hotels as well as A^F. So, the straight line is obtained by a simple linear regression analysis, based on empirical data. Its validity is checked by means of the Pearson's correlation coefficient, r, between both variables under consideration. The closer to one the coefficient is, the greater the validity of the straight line as a model is. Suárez Ibujes states a criterion to rate correlation between the two variables, as shown in Table 2:

Value	*Meaning*
-1	Negative perfect correlation
-0.9 a -0.99	Very high negative correlation
-0.7 a -0.89	High negative correlation
-0.4 a -0.69	Moderate negative correlation
-0.2 a -0.39	Low negative correlation
-0.01 a -0.19	Very low negative correlation
0	Non-existing correlation
0.01 a 0.19	Very low positive correlation
0.2 a 0.39	Low positive correlation
0.4 a 0.69	Moderate positive correlation
0.7 a 0.89	High positive correlation
0.9 a 0.99	Very high positive correlation
1	Perfect positive correlation

Table 2: Pearson correlation coefficient rating scale.
Source: Suárez Ibujes (2011). Karl Pearson's correlation coefficient.

The latter article describes how to calculate Pearson's correlation coefficient when data are not grouped by intervals according to Equation 2.

$$r = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sqrt{\sum (x-\bar{x})^2 \sum (y-\bar{y})^2}}$$

Equation 2: Correlation coefficient for ungrouped data case.

After verifying the existence of a linear relationship with at least a moderate positive correlation between both variables, monthly water consumption and the number of overnight stays, in affirmative case, the specific consumption, "a", can be easily calculated by the Equation 3.

$$a = A/P = m^A + A^F /P$$

Equation 3: Water consumption for a hotel, in litres per person per day, versus overnight stays.

This is a parabola with a horizontal asymptote a = mA. However, this curve is only interesting from a practical standpoint, this occurs in an interval of overnight stays ranging from 29% occupancy to 120% occupancy, considering occupations over 100% using extra beds.

The first analysis involves calculating the parameters of the monthly water consumption versus overnight stays straight line, which are also parameters of the water specific consumption curve. This analysis will be performed not only for the whole year, but also for both summer and winter seasons. Complementarily, average water consumption will also be calculated for the considered periods.

The second category analysis involves representing specific consumption versus the occupancy percentage for all hotels. Only specific consumptions and occupancy percentages can be analysed together. From all these data, several models will be tested by means of linear regression analysis. The empirical equation that has the higher correlation coefficient will be chosen. As in the case of the analysis of the first category, this analysis will be performed not only for the whole year, but also for both summer and winter seasons. Also, both normal and optimal consumptions will be studied, which will be obtained similarly to those of the first category.

5. WATER CONSUMPTION ANALYSIS FOR EACH HOTEL

5.1) NORMAL WATER CONSUMPTION FOR EACH HOTEL:

Normal consumption of a hotel refers to average consumption in each month, as opposed to optimal consumption. Table 3 shows the normal consumption parameters of hotels Linda, Leo, Belsana, Bellevue Club, Vistanova and Lagomonte. The first three have specific average water consumption very close to 200 L/pax/day, the second two exhibit a slightly higher consumption, and Lagomonte has specific average water consumption strikingly higher. This particular hotel has a number of recurring problems related to huge leaks in its swimming pool, which could explain such high consumptions. The correlation coefficient is acceptable, above 0.7 in all cases, except Belsana, that has a low correlation coefficient, indicating that the empirical straight line of the latter is just a rough approximation of its water consumption performance. Fixed consumption in some cases results in negative values since it is an empirical method, and only occurs for very low occupancy values, always less than 29%. For the Leo hotel, positive values of the parameter A are achieved with an occupancy over 1.78%. The variable A, gross monthly water consumption, only makes sense for positive values.

	Case					
Parameter	*Linda*	*Leo*	*Belsana*	*Bellevue*	*Vistanova*	*Lagomonte*
Specific consumption yearly average (L/pax·month)	203	202	214	262	238	330
R	0.855	0.758	0.579	0.891	0.702	0.763
m^A	186	206	126	184	132	175
A^F	142,671	66,066	359,281	6,395,957	715,562	1,985,506

Table 3: Water consumption for a whole year parameters of the studied hotels. 2003-2012 period.
Source: Own elaboration.

Data of Table 4 do not generally exhibit wide variations of specific consumption. The very sharp drops in the correlation coefficients, from high positive correlation to moderate positive correlation, are very eye-catching, except in the case of Bellevue, which is higher than 0.9. The low correlation coefficients in summer means a greater dispersion of consumption values and therefore the linear model may not fit properly in that season separately from the winter.

	Case					
Parameter	*Linda*	*Leo*	*Belsana*	*Bellevue*	*Vistanova*	*Lagomonte*
Specific consumption average (L/pax·month)	*209*	*218*	*186*	*237*	*264*	*324*
R	*0.448*	*0.456*	*0.687*	*0.903*	*0.459*	*0.594*
m^A	*110*	*131*	*103*	*211*	*212*	*97*
A^F	*1,019,065*	*1,479,343*	*1,180,988*	*3,204,986*	*533,513*	*3,547,556*

Table 4: Summer season water consumption parameters of the studied hotels. 2003-2012 period.
Source: Own elaboration.

As shown in Table 5, there is a high positive correlation between water consumption and overnight stays for all hotels in winter season, except in the case of Leo hotel, where the correlation is moderate positive. Average specific water consumption of hotel Belsana in winter is almost as big as water consumption in Lagomonte. This fact is noteworthy since Belsana hotel gets the lowest value of this parameter in summer. Belsana hotel has been opened in winter season only four years and less than one month per year. Puerto Colom village is a holiday markedly seasonal destination of summer. Therefore, the data that has been provided over the winter in this particular hotel are distorted by being a period less than one month, which combine important occupation drops given by the end of the season, and what in hotel is called "the closure of the hotel", which comprises the cleaning and general maintenance works to prepare the hotel to endure the winter. These reasons make results few reliable.

	Case					
Parameter	*Linda*	*Leo*	*Belsana*	*Bellevue*	*Vistanova*	*Lagomonte*
Specific consumption average (L/pax.month)	*192*	*186*	*348*	*275*	*238*	*357*
R	*0.898*	*0.687*	*0.827*	*0.825*	*0.702*	*0.826*
m^A	*105*	*103*	*157*	*169*	*132*	*336*
A^F	*670,436*	*1,180,988*	*663,094*	*5,549,305*	*715,562*	*28,833*

Table 5: Winter season water consumption parameters of the studied hotels. 2003-2012 period.
Source: Own elaboration.

5.2) OPTIMAL WATER CONSUMPTION FOR EACH HOTEL:

Optimal water consumption has been calculated for each month as the minimum consumption reached by the hotel in that month over the study period and 10% occupancy interval.

Table 6 shows the optimal consumption parameters of the hotels for the entire year.

	Case					
Parameter	*Linda*	*Leo*	*Belsana*	*Bellevue*	*Vistanova*	*Lagomonte*
Specific consumption yearly average (L/pax.month)	*178*	*183*	*191*	*216*	*208*	*270*
R	*0.972*	*0.824*	*0.779*	*0.893*	*0.679*	*0.957*
m^A	*164*	*144*	*121*	*218*	*102*	*227*
A^F	*96,031*	*501,027*	*292,040*	*-133,890*	*686,814*	*227,336*

Table 6: Optimal water consumption parameters of the studied hotels for the entire year. 2003-2012 period.
Source: Own elaboration.

Table 7 shows the optimal consumption parameters of the hotels for the summer season.

	Case					
Parameter	*Linda*	*Leo*	*Belsana*	*Bellevue*	*Vistanova*	*Lagomonte*
Specific consumption average (L/pax.month)	*182*	*200*	*168*	*219*	*220*	*299*
R	*0.721*	*0.448*	*0.845*	*0.989*	*0.381*	*0.766*
m^A	*148*	*111*	*142*	*207*	*54*	*139*
A^F	*357,704*	*1,513,264*	*126,336*	*1,371,034*	*1,465,717*	*2,296,107*

Table 7: Optimal summer season water consumption parameters of the studied hotels. 2003-2012 period.
Source: Own elaboration.

Table 8 shows the optimal consumption parameters of the hotels for the winter season.

	Case					
Parameter	*Linda*	*Leo*	*Belsana*	*Bellevue*	*Vistanova*	*Lagomonte*
Specific consumption average (L/pax.month)	*179*	*180*	*348*	*275*	*217*	*317*
R	*0.983*	*0.771*	*0.827*	*0.998*	*0.681*	*0.934*
m^A	*141*	*82*	*157*	*215*	*116*	*330*
A^F	*264,730*	*1,221,630*	*663,094*	*- 491,310*	*608,923*	*- 263,550*

Table 8: Winter season optimal water consumption parameters of the studied hotels. 2003-2012 period.
Source: Own elaboration.

6. OVERALL ANALYSIS OF CONSUMPTIONS

From now on, water consumptions from all hotels will be analysed together. In this case, independent variable will be monthly percentage of occupation instead of the number of overnight stays. This is denoted by the term “global analysis”.

6.1) OVERALL ANALYSIS OF NORMAL CONSUMPTIONS:

Normal consumption data will be studied firstly, in the same way as water consumption is studied for each hotel. Table 9 shows different empirical models for normal water consumption in summer season and includes their corresponding correlation coefficients. Independent variable is percentage of occupation (p). The function that best fits the overall data is the power function, with a very acceptable coefficient of correlation.

Type	*Equation*	R^2
Power	a=5251.3·p ^(-0.703)	0.824
Linear	a=-7.2989·p+952.38	0.282
Exponential	a=768.07 e ^(-0.013·p)	0.6232
Logarithmic	a=-495.7 ln (p) + 2419.5	0.5471
Polynomial	a=0.1438·p^2 – 28.671p + 1502.9	0.4586

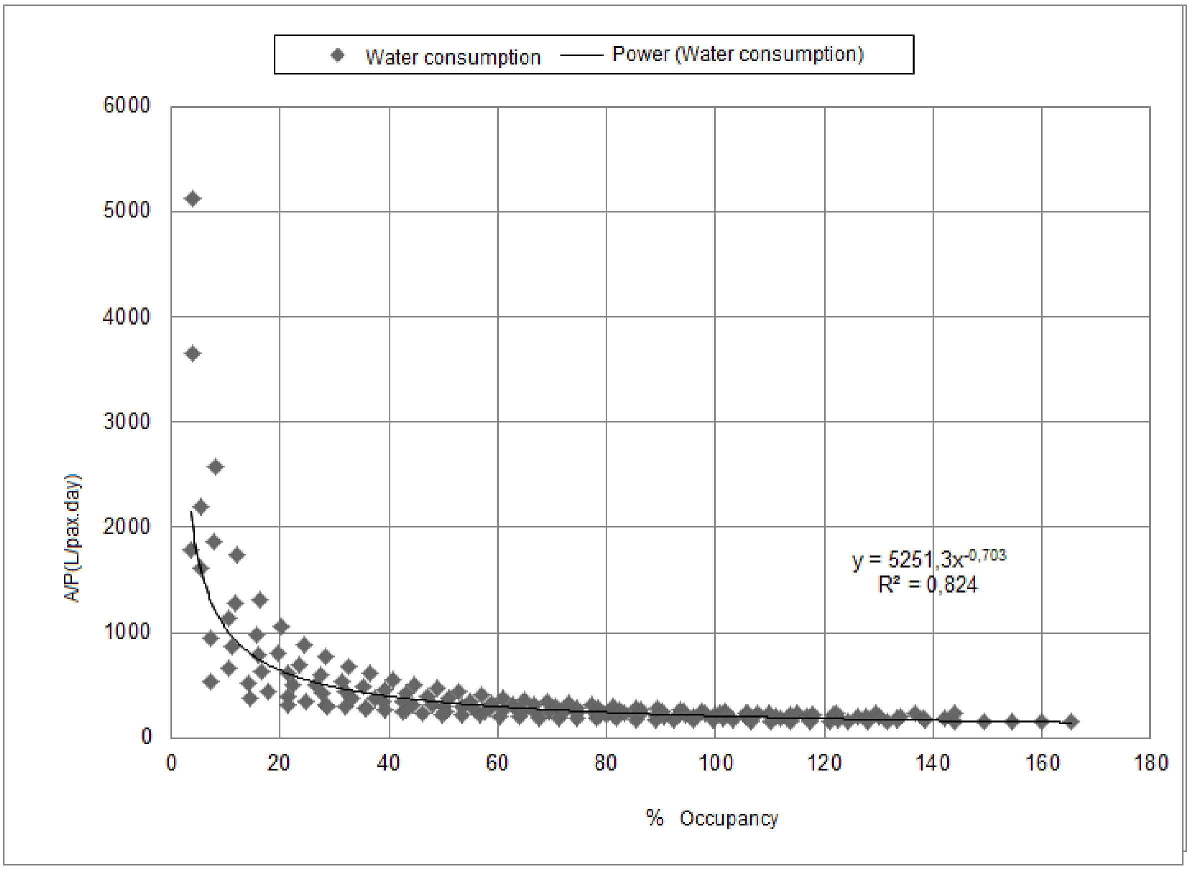
Table 9: Models for global normal consumption in summer season.
Source: Own elaboration.

Therefore, the summer water consumption function for the sample of hotels from Mallorca is described by Equation 4.

$$a=5251.3 \cdot p^{-0.703}$$

Equation 4: Summer season normal water consumption function for the hotel sample.

This function is represented in Graph 1.



Graph 1: Summer season normal global water consumption curve. 2003-2012 period.
Source: Own elaboration.

Table 10 shows the different models of normal consumption and the corresponding correlation coefficients for the winter season. Again this case, the power function is the function which best fits the data, although the correlation coefficient is much worse than in summer season case.

Function type	*Equation*	R^2
Power	a=1359.1 p ^(-0.409)	0.6109
Linear	a=-2.7661·p+496.08	0.2792
Exponential	a=437.22 e ^(-0.007·p)	0.4335
Logarithmic	a=-179.7 ln (p) + 1019.4	0.5015
Polynomial	a=0.0508·p^2 – 10.282·p + 689.14	0.4586

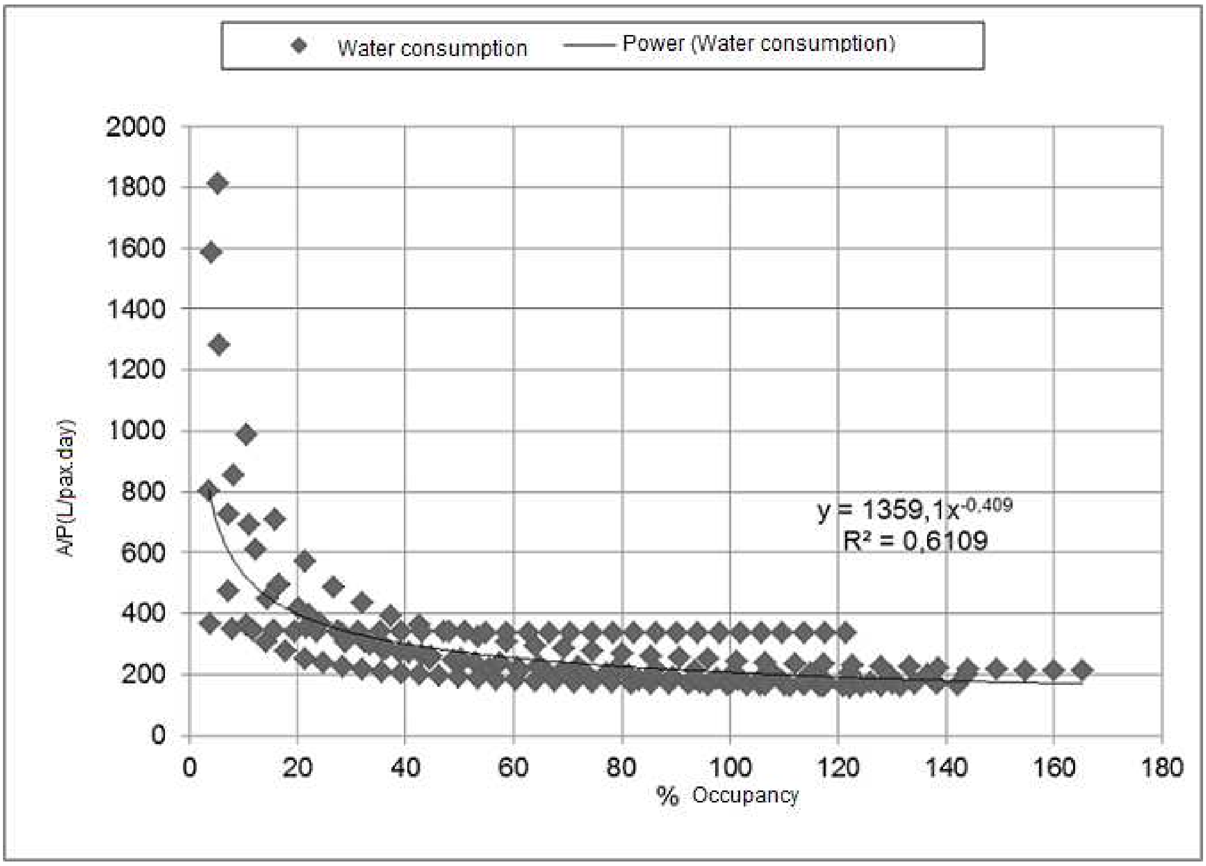
Table 10: Models for global normal consumption in winter season.
Source: Own elaboration.

Thus, the winter water consumption function for the sample of hotels is described by Equation 5.

$$a=1369.1 \cdot p^{-0.409}$$

Equation 5: Winter season normal water consumption function for the hotel sample.

The graph 2 shows normal water consumption curve for the hotel sample in winter season, without optimization. This curve will be denoted as normal global water consumption curve.



Graph 2. Winter season normal global water consumption curve. 2003-2012 period.
Source: Own elaboration.

Table 11 shows several models of normal water consumption for whole year and their correlation coefficients. Again, the function that best fits the overall data is the power function, although the correlation coefficient is a bit low.

Function type	*Equation*	R^2
Power	a=2673.8·p ^(-0.556)	0.6912
Linear	a=-5.046·p+724.81	0.2283
Exponential	a=579.85 e ^(-0.01·p)	0.5111
Logarithmic	a=-338.2 ln (p) + 1721	0.4338
Polynomial	a=0.0973·p^2 –19.477p + 1096.1	0.3662

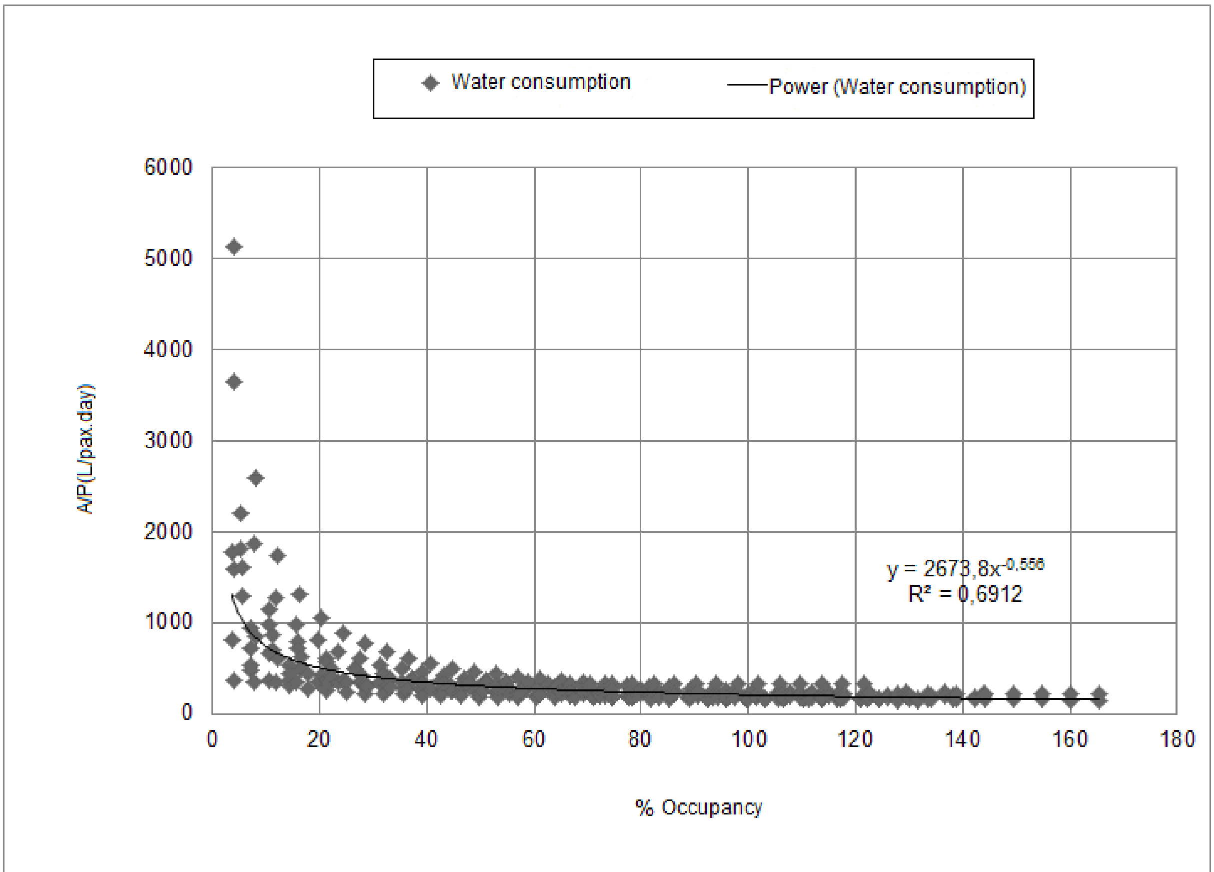
Table 11. Normal global water consumption models for the whole year.
Source: Own elaboration.

Therefore, normal global water consumption curve for the studied sample of hotels will be defined by the power function shown in Equation 6. In this case, correlation coefficient is lower than those coefficients from seasonal curves.

$$a=2673.8 \cdot p^{-0.556}$$

Equation 6: Normal Global water consumption of sample of hotels for whole year.

The corresponding function is show in Graph 3.



Graph 3. Normal global water consumption curve for the whole year. Studied period 2003-2012.
Source: Own elaboration.

6.2) OPTIMAL GLOBAL WATER CONSUMPTION ANALYSIS:

Specific water consumption data are grouped in steps of 10% occupancy. Minimum water consumption data are calculated as the minimum values for each month, year and 10% occupancy interval.

Table 12 shows the different models of optimal consumption for summer season and their correlation coefficients. Once again, the model that best fits the data is the power function. Its correlation coefficient is excellent in this case.

Function type	*Equation*	R^2
Power	a=649,69·p ^(-0.314)	0.9183
Linear	a=-1.1767·p+275.28	0.4576
Exponential	a=263.3 e ^(-0.005·p)	0.5957
Logarithmic	a=-78.54 ln (p) + 508,03	0.8281
Polynomial	a=0.0217·p^2 – 4.4357p + 363.38	0.7191

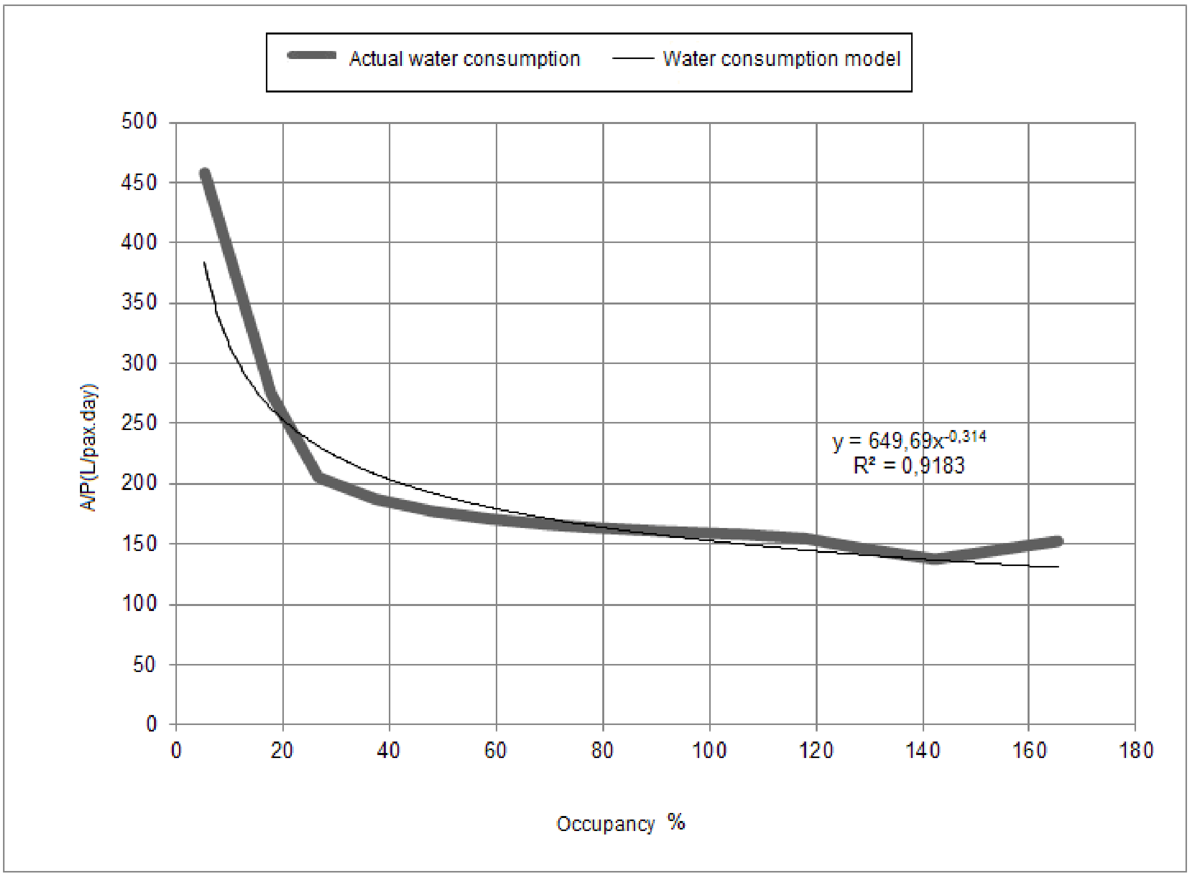
Table 12. Optimal Global water consumption models for summer season.
Source: Own elaboration.

Consequently, optimal water consumption curve for the studied sample of hotels in summer season will be defined by the power function shown in Equation 7.

$$a=649.69 \cdot p^{-0.314}$$

Equation 7: Summer season optimal water consumption curve for the studied hotels.

This function is drawn in Graph 4.



Graph 4. Summer season optimal water consumption curve for the sample of studied hotels.
Source: Own elaboration.

Table 13 shows different optimal water consumption models for the studied sample of hotels in winter season, as well as their correlation coefficients. Power function is the best one. Its correlation coefficient is very close to 0.9. This fact implies a very high correlation between both variables.

Function type	*Equation*	*R^2*
Power	a=570.66·p ^(-0.268)	0.8969
Linear	a=-0.9235·p+264.11	0.5592
Exponential	a=260.15 e ^(-0.004·p)	0.621
Logarithmic	a=-61,29 ln (p) + 446.39	0.8685
Polynomial	a=0.0181·p^2 – 3.6733·p + 339.67	0.8022

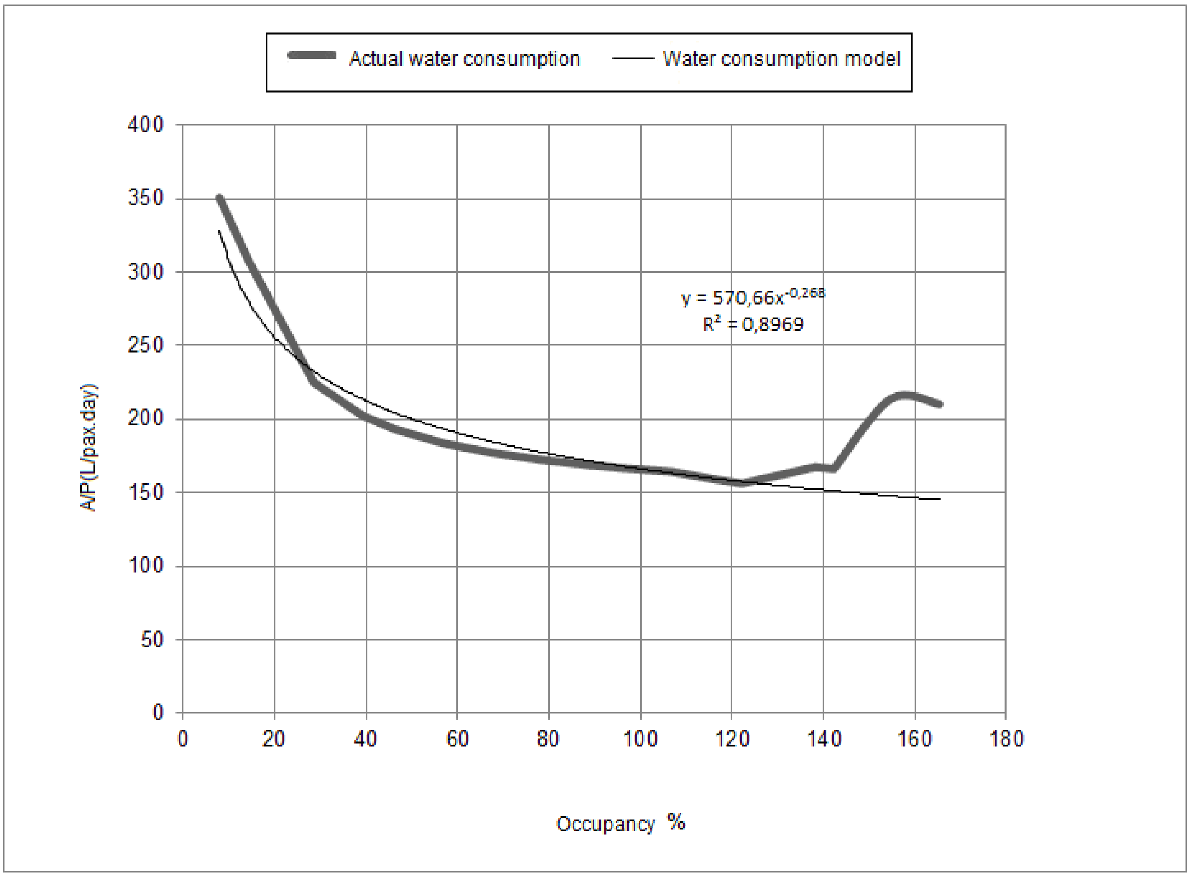
Table 13. Winter season optimal water consumption models for the sample of studied hotels.
Source: Authors.

Therefore, winter season optimal water consumption curve for three star hotels in Mallorca is power function described by Equation 8.

$$a=570.66 \cdot p^{-0.268}$$

Equation 8: Winter season optimal winter water consumption curve for the studied sample of hotels.

This function is drawn in Graph 5.



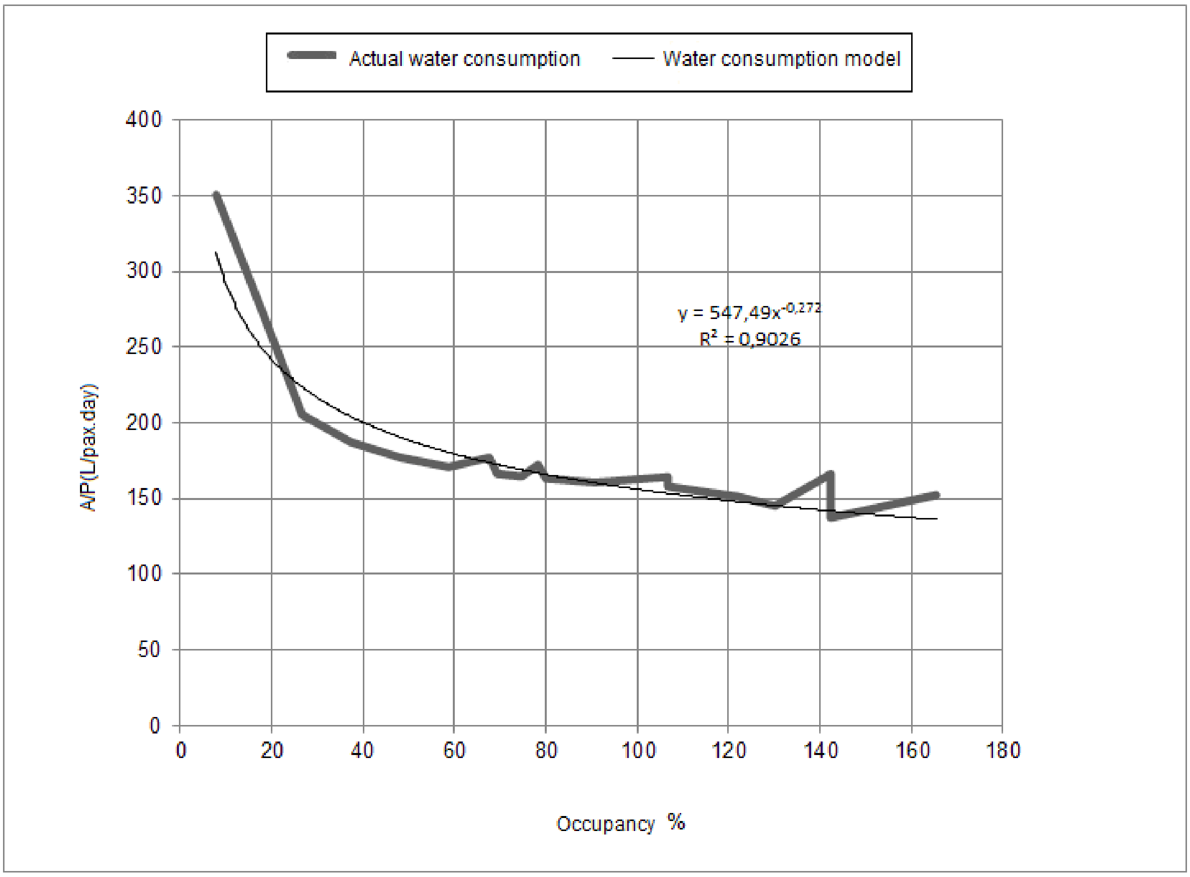
Graph 5. Winter season optimal global water consumption curve for the sample of studied hotels.
Source: Own elaboration.

Table 14 shows different optimal water consumption models and their correlation coefficients. Power function, with a correlation coefficient slightly higher than 0.9, fits the data much better than the other equations.

Function type	*Equation*	R^2
Power	a=547.49·p ^(-0.272)	0.9026
Linear	a=-0.9235·p+264.11	0.5592
Exponential	a=246.35 e ^(-0.004·p)	0.6359
Logarithmic	a=-59.94 ln (p) + 429,49	0.8495
Polynomial	a=0.0148·p^2 – 3.1675·p + 313.77	0.7922

Table 14. Annual optimal global water consumption models.
Source: Own elaboration.

This function is drawn in Graph 6.



Graph 6. Annual global optimal water consumption curve for the studied hotels.
Source: Own elaboration.

7. CONCLUSIONS

Both annual and seasonal water consumption curves have been obtained for a sample of hotels from a well-defined segment of hotel industry. This group or curves refer not only to normal, but also optimal consumption.

The method used to model this hotel industry segment could be used to model any other segment of this industry.

Since models have been calculated by means of statistical methods, the bigger the source is the more reliable are the models obtained, because of the consistency in the models applied.

Therefore, the analysis of water consumption optimization for a particular hotel is possible, simply by comparing the consumption of it, with the optimal model of hotel segment.

The vast majority of values of the correlation coefficients are lower in the case of normal operations, both of a particular hotel as the hotel group, compared with the corresponding optimized models so we can infer that the method design support for debugging optimized models noise, present in the data base.

The developed method leads to conduct new experiments in other hotels with similar characteristics to each other, but completely different from those studied here; as hotels in other destinations such as the Caribbean or even city hotels. The method to obtain the corresponding model can thus be tested in the same manner as in the case studied by other accommodation, and the goodness of the results can be measured by the Pearson coefficients, in the same way as in the study presented here.

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