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# Environmental Control for the Industry: A Water Consumption Model

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***Abstract:*** ***The service industry has not as developed control systems for water consumption as the rest of the industry. This article develops a method to get adjusted, to each company, mathematical models that relate water consumption versus occupation, and the proof for the case of the Spanish tourist industry, which is the most important in the country. Each model is validated by the square of the Pearson correlation coefficient. It is concluded that the methodology displayed is acceptable as Pearson coefficient values above 0.69 are obtained in the examples analyzed, opening a new field for further research.***

***Keywords:*** **Consumption Model (CM), Water Consumption (WC).**

## I. INTRODUCTION

The consumption of water and energy are the second most important cost item in hospitality, after staff expenses. It is clear that success in managing a hotel establishment is closely linked to the implementation of reliable control system and target consumption without reducing comfort of customers.

In addition to financial benefits, reducing water consumption leads to social and environmental benefits. The growing public awareness of these issues has contributed to increased demand from customers on the environmental aspects of the hotels. Therefore, the adoption of management techniques and energy efficient water enhances the reputation of a hotel and helps to attract more customers, and forming part of the strategy of continuous improvement of any Environmental Management System.

It has been taken as an example data monthly water consumption of three star hotels sunny beach in Majorca Island, Spain.

Needless to correctly choose the local hotel segment any other, the method is completely reproducible. Both total water consumption and specific per person per day from 2003 to 2013 inclusive were analyzed. Most important from a practical point of view are specific consumption, they allow comparison between hotels with number of seats capacity is different The need to improve competitiveness in the hospitality industry has been widely treated in the literature, as indicated by Pulido, J. 2011 in his article " Analysis of the role of international financial institutions in the financing of tourism." There management software that automate control staff working on site and streamline the processing of information that are used in hotels today are programs of enterprise resource planning (ERP ) as Navision Financials, Navihotel , Verial or Prestige . An ERP system is a software application that allows you to manage all business processes of a company in an integrated manner, as defined Florence Chiesa in his article: Methodology for selection of ERP systems. In the hospitality module we can find the same information from management about the various departments, spending results in both personal and incidents, and materials.

However, the management of water consumption is too coarse. The ERP simply allow the introduction of daily meter data and analysis monthly consumption per person, but do not calculate the mathematical model of consumption of the hotel itself, much less the model of water consumption target of every hotel chain or in particularly in terms of water consumption per occupied room.

Hospitality savings programs are designed Chain sometimes as part of environmental measures targeted many times by the quality department. Databases get information operations performed on the integrated management system (ERP).

Some authors have tried to obtain consumption patterns. Thus, the article " Tools for business energy management", Monteagudo Y., describes a system in which , without any data filtering and segmentation by type of hotel , a straight consumption is obtained regarding energy exclusively occupation , as a parable consumption rate with respect to occupation without actually obtain optimal curves.

In the doctoral thesis Rivero Rodríguez , P., led by Dr. Trujillo Armas, J. , entitled "Energy Rationalization in hotel facilities : technical analysis for a new project based on the " cogeneration " , by optimizing curves thermal and electrical demands inclusive of hot water services , cold, sea water desalination and electricity of a "type hotel ." Schedule energy curves describes his studies, and based upon a model of hotel , defining different energy consumption by formulas basic consumer segments , eg dishwasher.

J. Molina et al., in its "consumption Estudi d' Aigua als edificis the metropolitan region of Barcelona" studies the percentages of anticipated savings in relation to the various classical general water saving measures. The article " Reflections on energy consumption in the Cuban hotel industry ', Cabrera , O. define linear regressions of energy consumption with respect to the number of occupied rooms , obtaining regression rates the same , concluding that there are factors other occupation , that influence consumption of hotel facilities which are

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climate, the hotel category and type of tourism. Interestingly article Vicente Cruz , MA , "Obtaining the demand curve for water tour Acapulco , Guerrero " in that if a mathematical model based on the economic theory of demand for two areas of Acapulco is obtained. It is a logarithmic unit model number of rooms occupied by liters consumed, depending on other variables also logarithmic. However, only groups hotels by location, regardless of other variables to discern different types of hotels, such as the influence of the height of the hotel building.

In their study of uses and water savings in hotels in Hong Kong -Ming Shi, D. et al. 2002 a multiple regression analysis is used to study the variables that influence water consumption of a city hotel. Trujillo also Armas, F. in Article Energy Simulation accommodations mathematical model: analysis in the Canary Islands, proposes a mathematical model for heat and power consumption, segregated for each subsystem, operating time and load variation. For this, the first author set the variables affecting consumption schedules, getting daily consumption by a computer program data storage , obtaining an admissible error of + -12 %. However, in other modeling industry consumption is commonplace. Thus, energy modeling , electrical systems in industrial processes is widely reported in the literature: patterns of energy supply Samoulidis open loop , JE 1980 , the linear programming model of the U.S. electricity industry Hillsman et al, 1988; . Models that allow analysis of a single plant from an industry models Pilati and Sparrow, 1980, the analysis model developed energy resources for the gas industry U.S. TERA whose utility is described by Limaye and Sharko in 1974; updated strategic models as described by Placket et al reviews. 1982, the dynamic linear programming model for energy resources Rapoport, 1975 review paper or energy modeling Jebaraj , S. et al. 2006 . Report also called engineering models (bottom- up) , getting to represent an energy system in detail , considering it as a set of technologies for production, distribution and final energy demand competing ( González Hidalgo , I., 2005) and use a variety of mathematical tools , among which include control panels , boxes production and consumption versus time diagrams consumption versus production boxes specific consumption versus production , and Pareto charts control systems by UNE

Finally, note metaborder models, such as those already used to measure efficiencies between different groups of hotels, but only in terms of environmental variables and technological Assaf , A. et al. 2010.

Thus in contrast to what happens in the rest of the industry, there are no models in catering to appraise accurately the efficiency of a hotel regarding their optimal consumption, much less no models to assess this efficiency for a group of hotels. Everything is based on the intuition that comes from experience manager over the years especially in mansions but also in large chains, but intuition can not necessarily be translated into a vague and not entirely objective assessments. 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.

| | Linda | Leo | Belsana | Bellevue Club | Vistanova | Lagomonte |
|---|---|---|---|---|---|---|
| Type | Hotel | Hotel | Hotel and apartments | Apartments | Hotel | Hotel |
| Hotel chain | Hotetur-Roc | Hotetur-Roc | Hotetur-Bluebay | Hotetur-Bluebay | Hotetur-Bluebay | Hotetur-Bluebay |
| Stars/Keys | 3 | 3 | 3 | 3 | 3 | 3 |
| 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 |
| Spa | No | No | Yes | No | No | No |
| Electronic drive for water pumping | Yes | No | No | No | Yes | No |
| Working laundry | No | No | No | No | Yes | Yes |
| Study time range | 2003-2008 | 2003-2008 | 2003-2013 | 2003-2013 | 2003-2013 | 2003-2013 |

**Table 1. General data of premises**

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## II. METHODOLOGICAL APPROACH

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.

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.

All empirical relations are obtained for both normal and optimal consumptions. The normal consumption analysis includes all consumptions that have passed the aforementioned filters.

***Water consumption for each hotel:***

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. Article: Karl Pearson's correlation coefficient**

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

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 $a = m^A$.

The first analysis involves calculating the parameters of the monthly water consumption versus overnight stays

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straight line, which are also parameters of the water specific consumption curve.

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.

| | Case | | | | | |
|---|---|---|---|---|---|---|
| **Parameter** | Linda | Leo | Belsana | Bellevue | Vistanova | Lagomonte |
| Specific consumption yearly average (L/pax·month) | 203 | 203 | 264 | 235 | 272 | 288 |
| R | 0.855 | 0.708 | 0.665 | 0.947 | 0.679 | 0.855 |
| $m^A$ | 186 | 194 | 143 | 231 | 281 | 206 |
| $A^F$ | 142,671 | 127.182 | 550.274 | 391.567 | 337.870 | 1,240.299 |

**Table 3. Water consumption for a whole year parameters of the studied hotels. 2003-2013 period**

Finally, making a change of variable, such that the average occupancy rate, p(%) in a month:

p(%)=(P/maximum capacity)*100
and then:

$a=m^A+ (A^F/(p(\%)*\text{maximum capacity}/100))$

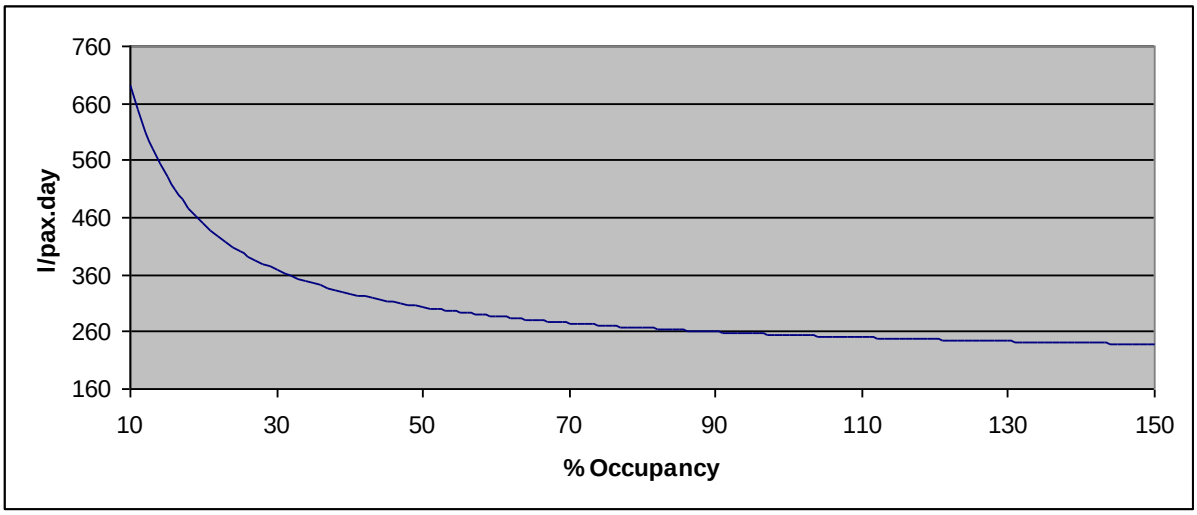
**Equation 3. Linear equation of specific water consumption in hotels**

So, in the case of Lagomonte:
A= 36.495*p+(1.240.299)

**Equation 4. Linear equation of water consumption in Lagomonte**

a= 206,95+7.033/p

**Equation 5. Linear equation of specific water consumption in Lagomonte**




**Graph 1. Lagomonte: global water consumption curve. Studied period 2003-2013**

***Overall analysis of consumptions:***

Normal consumption data will be studied 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.

| **Parameter** | Majorca 3* |
|---|---|
| Specific consumption yearly average (L/pax·month) | 229 |
| R | 0,897 |
| $m^A$ | 233 |
| $A^F$ | 91.364 |
| Capacity | 205.726 |

**Table 4. Water consumption for a whole year parameters of the overall analysis. 2003-2013 period**

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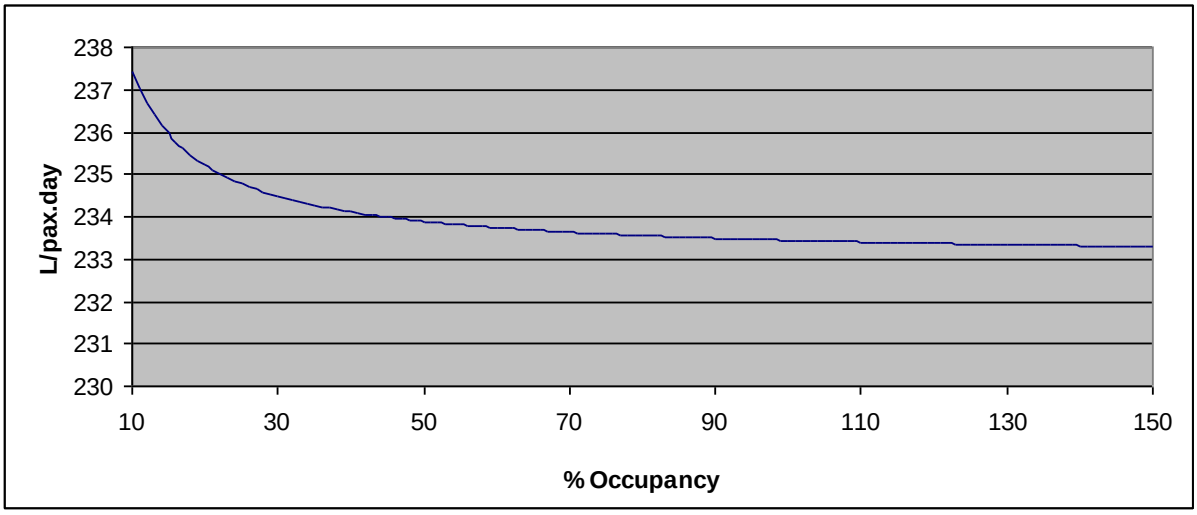
So, doing the same change of variable:

a= 84.420*100/p*205.726

**Equation 6. Linear equation of specific water consumption of the overall analysis. 2003-2013 period**




**Graph 2. Overall analysis: global water consumption curve. Studied period 2003-2013**

## III. CONCLUSIONS

Annual water consumption curve has 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. 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, or even other industries. 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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