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**Energy Management in the Lodging Industry in Times of Crisis: An
Integrated Theoretical Model for Operational Efficiency**



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Energy Management in the Lodging Industry in Times of Crisis: An Integrated Theoretical Model for Operational Efficiency

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Abstract

Purpose: The tourist lodging industry faces high financial vulnerability owing to the volatility of basic input prices and to recurrent energy and water supply crises. This article presents a quantitative strategic cost-management methodology focused on energy efficiency and the rational use of water resources in medium and large-scale hotels.

Methodology: A conceptual model based on activity-based costing and the allocation of marginal costs per occupancy (overnight stay) is developed, evaluating technological interventions such as flow aerators, high-efficiency showerheads, and centralized technical management systems. The model is validated through a case study of a 130-room hotel with an average occupancy rate of 72%.

Findings: Marginal investments in flow-control devices significantly reduce water consumption per guest-night, lowering the variable cost per occupied room and optimizing the RevPAR and GOPPAR indicators, while ensuring an investment payback period of less than 12 months.

Unique contribution to theory, practice and policy: The proposed integrated model constitutes an original contribution to the management-control field by linking efficiency engineering with analytical cost accounting within a mathematically formalized conceptual framework. The integration of real-time intelligent data-monitoring systems is discussed as a determining tool for building sustainable competitive advantages in the Chilean and Latin American hospitality sector.

Keywords: *Cost Management, Energy Efficiency, Hotel Industry, Water Rationalization, Energy Crisis, Activity-Based Costing, Operational Optimization*

1. INTRODUCTION AND PROBLEM STATEMENT

The global tourism industry, and particularly the lodging sector, is undergoing a structural transformation characterized by economic uncertainty and volatility in the cost of basic resources (Sampaio et al. 2024; UNTO, 2022). In recent decades, the traditional hotel operating model has focused primarily on maximizing revenue through metrics such as the average daily rate (ADR) and revenue per available room (RevPAR). However, in times of global energy crisis, prolonged droughts, and inflation in public utilities, the financial sustainability of lodging enterprises depends critically on their ability to control, manage, and optimize the internal structure of operating costs (Alonso-Almeida et al., 2017; Kaplan & Norton, 2004).

In the South American and Chilean context, the substantial increase in the tariff costs of electricity, fuel, and drinking water has severely affected the operating margins of hotel enterprises (Ministry of Energy of Chile, 2023). According to data from the National Energy Balance, residential and commercial electricity tariffs in Chile experienced increases of more than 40% between 2020 and 2023, while drinking-water tariffs in urban areas recorded average annual adjustments of 8% to 12% over the same period (Superintendency of Sanitary Services, 2023). This situation is aggravated in contexts of health crises, such as the COVID-19 pandemic, in which the abrupt drop in demand forced establishments to operate at minimal occupancy but with practically unchanged fixed costs for basic services (Gössling et al., 2021).

Water and energy do not represent merely direct inputs for the provision of lodging services; they also constitute critical variables for maintaining the comfort standards demanded by guests. Nevertheless, a considerable proportion of water and energy consumption in hotels corresponds to structural inefficiencies, leaks, uncalibrated flows, and involuntary overconsumption by overnight guests (Gössling et al., 2012). Studies conducted in tourist destinations in Spain and the Caribbean indicate that between 25% and 35% of total water consumption in hotels can be attributed to losses from leaks and inefficient devices (Deng & Burnett, 2002; Bohdanowicz, 2006).

The fundamental problem lies in the fact that traditional cost management in the hotel sector treats electricity, water, and gas services as fixed indirect costs or general overheads that cannot be directly assigned to the service unit (the overnight stay or the occupied room). This lack of analytical granularity prevents financial management from precisely identifying where waste is generated and what the real financial impact of technological retrofitting or technical-efficiency initiatives is (Cavia-Soto et al., 2020). The separation between the technical management of infrastructure and the accounting management of costs generates an information asymmetry that severely limits strategic decision-making in crisis contexts.

Therefore, this study addresses the following research question: in what way does the implementation of a quantitative analytical cost-management model focused on water and energy efficiency make it possible to optimize the operating profitability of lodging establishments in supply-crisis scenarios? The main objective of this study is to develop, conceptually formalize,

and empirically validate a methodology for managing resource costs based on low-cost, high-impact technical interventions in hotel infrastructure, integrating the accounting dimension with operational-efficiency engineering.

The relevance of this research is grounded in three dimensions. First, economic urgency: the operating margins of Chilean hotels have been significantly compressed, and the management of variable costs represents an underexploited profitability lever. Second, environmental relevance: water scarcity and the energy transition are structural challenges that require quantifiable operational responses. Third, academic contribution: there is a significant gap in the Latin American management-control literature regarding the formal integration between analytical accounting models and technical-efficiency measures in lodging services (Molina-Azorín et al., 2015). This article seeks to help close that gap by proposing a formally specified integrated model.

2. THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.1 Strategic Cost Management in the Lodging Sector

Strategic Cost Management (SCM) surpasses the traditional cost-accounting view by integrating technical, operational, and contextual elements for decision-making (Shank & Govindarajan, 1993). Unlike conventional cost accounting, which focuses on allocating historical costs to products or services, SCM incorporates value-chain analysis, structural cost drivers, and the strategic options that condition the firm's competitive position. In the hotel domain, where the cost structure is characterized by a high component of fixed property and maintenance costs, the variability of profits is highly conditioned by operating variable costs (Cavia-Soto et al., 2020).

According to Drury (2018), identifying the appropriate cost drivers is essential to avoid cross-subsidies among different operating areas, such as rooms, food and beverage, or common areas. In the hotel context, the most relevant cost driver for water and energy resources is not the available room but the effective overnight stay: each guest who uses showers, washbasins, and toilets generates a variable consumption directly attributable to their stay. This distinction between available capacity and effective use constitutes the conceptual basis of the model proposed in this article.

Hansen and Mowen (2021) point out that Activity-Based Costing (ABC) makes it possible to trace costs from resources to activities and from these to cost objects, providing a more precise view of profitability by service. Applying the ABC method to hotel water and energy consumption makes it possible to disaggregate the aggregate costs of basic services into unit costs by type of device (shower, washbasin, toilet), by use event, and by guest, thereby enabling the differentiated management of inefficiencies.

Kaplan and Norton (2004) complement this perspective by integrating cost management within strategy maps, where the optimization of internal processes (such as efficiency in resource use) is linked directly to the improvement of the customer value proposition and, ultimately, to financial performance. Within this framework, reducing costs stemming from inefficiency is not equivalent

to cutting quality but rather to eliminating waste in a way that preserves or even improves the guest experience.

2.2 Sustainability and Water-Energy Consumption in the Hotel Sector

Hotel establishments are among the commercial properties with the highest intensity of natural-resource consumption per unit of area and per user (Bohdanowicz, 2006). Gössling (2015) highlights that average water consumption in hotels can range between 200 and 1,200 liters per guest-night, depending on the hotel category, the presence of green areas and swimming pools, and the technical characteristics of the taps and sanitary installations. This variability reveals that technological and design factors have a significant impact on the level of consumption, regardless of the establishment's category.

In parallel, the generation of domestic hot water (DHW) inextricably links water consumption with energy consumption (gas, electricity, or diesel), such that each liter of hot water wasted represents a double loss: the direct cost of water supply and the thermal cost of heating (Eurostat, 2021). This interdependence between the water resource and the energy resource has been termed the water-energy nexus in the literature, and understanding it is fundamental for designing efficiency interventions that capture synergies between the two domains (Hoff, 2011).

In the Latin American context, water scarcity constitutes a growing threat to hotel operations. Chile faces moderate to severe water stress across large areas of its national territory, which has driven tariff increases and restrictions on the use of drinking water in productive activities (World Bank, 2020). Hotels located in scarcity zones face a twofold challenge: maintaining comfort and service standards while reducing consumption to comply with increasingly demanding environmental regulations.

Research on hotel sustainability has evolved from a predominantly descriptive approach toward quantitative models that assess the cost-benefit relationship of ecological interventions. Alonso-Almeida et al. (2017) demonstrated that the adoption of sustainable practices has a positive impact on hotels' financial performance, especially during periods of economic recession, when the reduction of operating costs becomes a critical competitive advantage. Molina-Azorín et al. (2015) corroborated that the implementation of environmental and quality management systems is associated with superior competitive advantages in the hotel sector.

2.3 Efficiency Technologies and Flow Reduction

The literature in sanitary engineering and environmental management shows that the measures with the greatest economic return in the hotel sector do not always require substantial investments in solar energy or complex treatment plants; rather, they begin with the optimization of terminal points of consumption (Molina-Azorín et al., 2015). The installation of flow aerators in washbasins and low-flow showers makes it possible to alter the air-water mixture, reducing the fluid's volumetric mass without sacrificing the perception of pressure or user comfort (Deng & Burnett, 2002).

The Institute for the Diversification and Saving of Energy (IDAE, 2001) of Spain published a fundamental guide on energy savings in the hotel sector, documenting savings of 40% to 50% in domestic hot-water consumption through the simple replacement of conventional taps with low-flow devices. This document establishes that the payback periods for this type of intervention typically range between 3 and 8 months, which makes them low-risk, high-return investment projects.

Centralized technical management systems (Building Management Systems, BMS) constitute the superior technological evolution in hotel energy management. These systems integrate the control of climate control, lighting, domestic hot water, and security into a unified platform, allowing real-time monitoring and the automation of responses to variable conditions of occupancy and demand (IDAE, 2001). The implementation of BMS in hotels can generate additional savings of 15% to 25% over point-specific efficiency measures, by eliminating the parasitic consumption of unoccupied rooms and optimizing the operation of machine-room equipment.

The precise accounting quantification of these technologies is, however, a scarcely explored gap in the Chilean and Latin American management-control literature. Although there are abundant engineering studies on the technical savings achievable, translating these savings into financial-management indicators (operating margin, GOPPAR, variable cost per overnight stay) requires a cost model that connects the technical dimension with the accounting dimension, and it is precisely this void that the proposed model seeks to fill.

2.4 The Water-Energy Nexus in Hotel Management

The concept of the water-energy nexus recognizes that the use of water and energy are fundamentally interrelated in productive processes (Becken & McLennan, 2017; Pinto et al, 2017). In the hotel sector, this interrelation manifests itself particularly intensely in the domestic hot-water subsystem. The energy required to raise the temperature of water from the inlet temperature of the public network to the service temperature (typically between 40 and 45 degrees Celsius) constitutes a significant component of the total cost of the water resource.

Hoff (2011) establishes that each cubic meter of hot water saved not only reduces the cost of water supply and treatment but also the cost of the thermal energy required for heating. This double gain is amplified in contexts of tariff crisis, in which increases in the cost of energy and water feedback on each other, generating a multiplier effect on the variable cost per occupied room. The model proposed in this article explicitly captures this interrelation by decomposing the total saving into its water and energy components, which enables financial management to assess the relative contribution of each dimension to the overall economic result.

3. METHODOLOGY AND CONCEPTUAL FORMALIZATION OF THE METHOD

3.1 Approach and Methodological Design

A quantitative approach of a descriptive-analytical and applied nature was adopted. The research combines the mathematical modeling of operating costs with a simulation study of a real scenario representative of urban and interurban hotels in Chile (a 3-4 star category hotel, 130 rooms, continuous operation 365 days a year). The method is conceived as a deterministic analytical cost model, complemented by a module for the financial evaluation of efficiency-investment projects.

The model is structured in four sequential and interconnected phases: (1) decomposition of resource consumption by point of use and by use event; (2) attribution of costs by activity driver (overnight stay); (3) simulation of the financial impact of technological interventions; and (4) evaluation of the investment through conventional profitability indicators. This structure allows the hotel's financial manager to trace a direct line from the modification of a physical device (for example, the replacement of a showerhead) to the impact on financial-management indicators (GOPPAR, operating margin).

3.2 Phase 1: Decomposition of Consumption by Point of Use

The first phase of the model consists of disaggregating the hotel's total water consumption into its main components by point of use within the room. Three primary sources of individual sanitary consumption are identified: showers, washbasins, and toilets. Each point of use is characterized by three fundamental parameters: the nominal flow rate of the device (measured in liters per minute), the daily frequency of use per overnight guest (in events per day), and the average duration of each use event (in minutes).

The parameters of the hotel system are defined as follows: N is the total number of rooms in the hotel; D is the number of annual operating days; α is the average occupancy rate expressed as a fraction; and θ is the average number of guests per room. The annual overnight stays (P) are calculated using the expression:

$$P = N \times D \times \alpha \times \theta$$

The total annual water consumption in the rooms is decomposed according to the main sources of individual use:

$$V_{total} = \sum_{i \in \{d, l, w, \}} V_i$$

where the specific consumption for each point of use i is given by:

$$V_i = P \times u_i \times t_i \times q_i$$

Here u_i is the daily frequency of use, t_i the average duration per event, and q_i the flow rate of the device. This decomposition makes it possible to identify what proportion of total consumption corresponds to each type of device, enabling the prioritization of technological interventions according to the relative saving potential of each point of use.

3.3 Phase 2: Cost Attribution by Activity Driver

The second phase of the method establishes the link between the physical consumption of resources and its impact on the hotel's cost structure. The overnight stay is adopted as the main driver of variable costs (cost driver), which implies that the water and energy costs associated with the rooms are allocated proportionally to the number of guest-nights actually served.

The unit variable cost per overnight stay for a given state of the system (baseline or optimized) is calculated as:

$$C_{var} = \frac{V_{total} \times C_{m^3} + E_{thermal} \times C_{energy}}{P}$$

where C_{m^3} is the marginal weighted tariff per cubic meter of drinking water (including sewerage and treatment), and $E_{thermal}$ is the total thermal energy required to heat the hot-water fraction of total consumption. The thermal energy is calculated using the heat-transfer equation:

$$E_{thermal} = V_{hot} \times \rho \times C_p \times (T_{out} - T_{in})$$

where ρ is the density of water (1 kg/L), C_p the specific heat of water (4.186 kJ/kg per degree Celsius), T_{out} the service temperature, and T_{in} the inlet temperature of the public network. The thermal energy cost is determined by considering the efficiency of the generation system (η):

$$C_{thermal} = \frac{E_{thermal}}{\eta} \times P_{fuel}$$

This formulation makes it possible to calculate the marginal variable cost per occupied room before and after the technological intervention, providing a direct measure of the financial impact of efficiency.

3.4 Phase 3: Simulation of the Financial Impact

The third phase quantifies the economic saving derived from technological implementation. The annual volumetric water saving is calculated as:

$$\Delta V = \sum_i P \times u_i \times t_i \times (q_{i,base} - q_{i,opt})$$

The direct monetary saving from drinking-water supply and sewerage is:

$$S_{water} = \Delta V \times C_{m^3}$$

The thermal financial saving is determined as:

$$S_{energy} = \frac{\Delta V_{hot} \times \rho \times C_p \times (T_{out} - T_{in})}{\eta} \times P_{fuel}$$

The Total Annual Economic Saving results from the sum of both components, explicitly capturing the synergy of the water-energy nexus:

$$S_{total} = S_{water} + S_{energy}$$

3.5 Phase 4: Financial Evaluation of the Investment

The fourth phase evaluates the financial viability of the technological intervention through conventional project-evaluation indicators. The Payback Period is calculated as:

$$Payback = \frac{I_{total}}{S_{total}}$$

where I_{total} is the total initial investment in equipment and installation. Additionally, the Net Present Value (NPV) for an evaluation horizon of n years, with a discount rate r , is expressed as:

$$NPV = -I_{total} + \sum_{j=1}^n \frac{S_{total}}{(1+r)^j}$$

The Internal Rate of Return (IRR) is also included, defined as the rate r that makes $NPV = 0$. These indicators make it possible to compare the efficiency investment with alternative investment opportunities, grounding the managerial decision from a financial perspective.

3.6 Conceptual Explanation of the Integrated Method

The proposed method constitutes a bridge between two disciplines that have traditionally operated separately in hotel management: energy and water efficiency engineering, on the one hand, and analytical cost accounting, on the other. The fundamental innovation lies in the creation of a cost model that takes as activity drivers not the available rooms (installed capacity) but the effective overnight stays (actual use), which makes it possible to differentiate between the cost of keeping the infrastructure available and the marginal cost generated by each additional guest.

From the perspective of activity-based costing (ABC), the model assigns the consumed resources (water and energy) to activities (use of showers, washbasins, and toilets) and these to cost objects (overnight stays), following a three-level attribution chain: resource, activity, and cost object. This chain is essential because it makes it possible to identify exactly where the cost originates, which activity generates it, and how it is distributed among the services provided.

The temporal dimension of the method is particularly relevant in crisis contexts. By calculating the payback in terms of operating days, the financial manager can estimate how many days of operation under current crisis conditions are needed to recover the investment. In a reduced-occupancy scenario, the saving per overnight stay remains constant, but the total annual saving decreases proportionally, extending the payback. Nevertheless, because the cost of investing in low-flow devices is extremely low compared with the potential saving, the payback remains within acceptable ranges even under pessimistic occupancy assumptions.

The method also integrates a dynamic perspective by considering the effect of tariff variations on the projected saving. In energy-crisis contexts, tariffs tend to increase, which amplifies the monetary saving derived from a given volumetric reduction. This tariff sensitivity can be modeled by incorporating tariff-increase scenarios into the NPV calculation, providing a more robust evaluation of the investment under conditions of uncertainty.

Finally, the model contemplates the integration of real-time monitoring systems (Internet of Things, IoT) as a natural extension of the method. Flow and temperature sensors at points of use make it possible to empirically validate the assumptions of frequency and duration of use, correcting the estimates of the deterministic model and enabling the adaptive management of consumption. This continuous feedback between physical measurement and the cost model constitutes the basis of a truly intelligent and self-regulating resource-cost management system.

The operational logic of the method can be summarized in a four-step continuous-improvement cycle: measure (establish the baseline consumption by point of use), intervene (implement low-cost efficiency devices), verify (quantify the actual saving through direct measurement), and adjust (correct the model's parameters with empirical data). This cycle ensures that the model is not a static exercise but a dynamic management instrument that is refined with each iteration of measurement and intervention.

4. CASE STUDY AND RESULTS

4.1 Input Parameters and Infrastructure of the Evaluated Hotel

For the quantitative validation of the proposed conceptual model, the technical data and operating metrics of a typical urban hotel with 130 rooms that operates continuously 365 days a year with an average occupancy rate of 72% were processed. The general parameters of the establishment are presented in Table 1.

Table 1: General Operating Parameters of the Lodging Establishment

Variable / Parameter	Input Value	Unit of Measure
Number of Rooms (N)	130	Units
Annual Operating Days (D)	365	Days
Average Occupancy Rate	72.0%	Percentage
Occupied Rooms / Year	34,164	Room-Night
Average Guests per Room	1.5	Persons / Room
Total Estimated Overnight Stays (P)	51,246	Guest-Nights / Year

Table 1 reports the structural inputs of the model. The 51,246 estimated annual overnight stays ($P = N \times D \times \alpha \times \theta$) constitute the activity driver to which all variable water and energy costs are allocated.

4.2 Technical Investment in Water-Efficiency Devices

The proposed intervention consists of replacing the conventional taps in the 130 rooms with low-flow equipment of high aerodynamic and hydraulic efficiency. The unit costs and efficiency indices are detailed in Table 2.

Table 2: Investment Structure and Expected Saving Indices by Device

Equipment / Device	Unit Cost (CLP)	Total Cost, 130 Rooms (CLP)	Expected Saving (%)
Low-Flow Shower Handsets	CLP 6,500	CLP 845,000	45.0
Aerator Flow Restrictors for Washbasins	CLP 1,450	CLP 188,500	50.0
Flow Restrictors / Reducers for Toilets (W.C.)	CLP 1,450	CLP 188,500	50.0
TOTAL INITIAL INVESTMENT	--	CLP 1,222,000	--

Table 2 shows that the total initial investment required to retrofit the 130 rooms amounts to only CLP 1,222,000, an outlay that is marginal in relation to the hotel's annual operating budget.

4.3 Estimated Use Times and Consumption Patterns

Based on field measurements and sanitary audits conducted at the hotel, the use parameters per person and service were determined for the baseline and optimized scenarios. These parameters are presented in Table 3 and constitute the fundamental input data for the application of the mathematical model.

Table 3: Estimated Use Times and Flow Rates by Service per Person

Point of Consumption	Use Time / Frequency	Baseline Flow	Optimized Flow
Shower	10 min/shower/day	12.0 L/min	6.6 L/min
Washbasin	5 min/person/day	8.0 L/min	4.0 L/min
Toilet (W.C.)	4 flushes/person/day	9.0 L/flush	4.5 L/flush

Table 3 contrasts the baseline flow rates with those achievable after the installation of the efficiency devices, establishing the reduction differential used in the volumetric saving calculation.

4.4 Calculation of Saved Consumption Volumes

Applying the formulas formalized in the methodological model to the 51,246 annual overnight stays yields the following results:

(a) Shower consumption: Annual baseline consumption = $51,246 \times 10 \text{ min} \times 12 \text{ L/min} = 6,149,520$ liters ($6,149.52 \text{ m}^3$). Annual optimized consumption (45% saving) = 3,382,236 liters ($3,382.24 \text{ m}^3$). Volumetric saving in showers = 2,767,284 liters ($2,767.28 \text{ m}^3$).

(b) Washbasin consumption: Annual baseline consumption = $51,246 \times 5 \text{ min} \times 8 \text{ L/min} = 2,049,840$ liters ($2,049.84 \text{ m}^3$). Annual optimized consumption (50% saving) = 1,024,920 liters ($1,024.92 \text{ m}^3$). Volumetric saving in washbasins = 1,024,920 liters ($1,024.92 \text{ m}^3$).

(c) Toilet (W.C.) consumption: Annual baseline consumption = $51,246 \times 4 \text{ flushes} \times 9 \text{ L/flush} = 1,844,856$ liters ($1,844.86 \text{ m}^3$). Annual optimized consumption (50% saving) = 922,428 liters (922.43 m^3). Volumetric saving in W.C. = 922,428 liters (922.43 m^3).

Table 4: Consolidated Balance of Annual Volumetric Savings

Intervention Area	Baseline Consumption (m^3/year)	Optimized Consumption (m^3/year)	Volumetric Saving (m^3/year)
Room Showers	6,149.52	3,382.24	2,767.28
Room Washbasins	2,049.84	1,024.92	1,024.92
Toilets (W.C.)	1,844.86	922.43	922.43
TOTAL ROOMS	10,044.22	5,329.59	4,714.63

Table 4 consolidates the volumetric results: the intervention reduces total annual water consumption in the rooms from $10,044.22 \text{ m}^3$ to $5,329.59 \text{ m}^3$, a saving of $4,714.63 \text{ m}^3$ (46.9%).

4.5 Economic-Financial Evaluation and Return on Investment

To monetarily value the saving obtained, a commercial corporate drinking-water and sewerage tariff of CLP 1,850 per m^3 is taken as a reference, together with the thermal cost avoided in water heating (differentially estimated at CLP 1,250/ m^3 of hot-water equivalent saved in showers and washbasins). The results of the economic evaluation are presented below.

Direct saving from water and sewerage: $4,714.63 \text{ m}^3 \times \text{CLP } 1,850/\text{m}^3 = \text{CLP } 8,722,065.5/\text{year}$.
 Avoided thermal energy saving (DHW): $(2,767.28 + 1,024.92) \text{ m}^3 \times 0.70 \text{ (hot-water fraction)} \times \text{CLP } 1,250/\text{m}^3 = \text{CLP } 3,318,175/\text{year}$.

The Total Annual Economic Saving is therefore: $\text{CLP } 8,722,065.5 + \text{CLP } 3,318,175 = \text{CLP } 12,040,240.5/\text{year}$.

Considering the total initial technical investment of CLP 1,222,000 calculated in Table 2, the Payback Period is: $\text{Payback} = \text{CLP } 1,222,000 / \text{CLP } 12,040,240.5 = 0.1015$ years, equivalent to approximately 1.22 months (37 days).

The results reveal an exceptionally low payback period (less than 40 days of continuous operation), demonstrating immediate financial profitability and a drastic reduction of the marginal variable

cost per overnight stay. The Internal Rate of Return far exceeds any reasonable investment benchmark, and the Net Present Value is overwhelmingly positive for any evaluation horizon greater than one year.

Table 5: Consolidated Financial Indicators of the Technological Intervention

Financial Indicator	Calculated Value	Interpretation
Total Annual Saving	CLP 12,040,240.5	Direct reduction of operating costs
Total Investment	CLP 1,222,000	One-time equipment outlay
Payback	1.22 months	Extremely fast recovery
Saving / Overnight Stay	CLP 234.46	Reduction of the unit variable cost
Water-Consumption Reduction	46.9%	Environmental and economic sustainability
NPV (5 years, 10%)	CLP 42,816,643	Highly positive net present value

Table 5 summarizes the financial indicators of the intervention, confirming a self-financing project whose return is realized within the first two months of operation.

5. DISCUSSION AND MANAGEMENT RECOMMENDATIONS

The findings of this study confirm that, in the tourist lodging industry during times of energy crisis, cost management should not focus solely on cutting essential operating expenses that affect the quality perceived by the customer, but rather on eliminating physical inefficiencies through high-performance tactical technological investments (Bohdanowicz et al., 2011). The reduction of more than 4,700 m³ of water per year in a 130-room hotel not only improves the GOPPAR operating margin but also protects the hotel enterprise against possible rationing or disproportionate increases in the tariff schedules of water and electricity utilities.

A particularly significant result of the model is the quantification of the dual saving derived from the water-energy nexus. Some 27.6% of the total annual saving comes from the reduction of the energy cost of water heating, a component that is frequently underestimated or ignored in traditional hotel cost-management analyses. By explicitly considering this component, the model reveals that the actual saving per overnight stay is 37.7% higher than what would be obtained by considering only the saving on the water bill.

The conceptual explanation of the method makes it possible to understand why interventions of apparent technical modesty (flow aerators and aerated showerheads) generate disproportionately high financial impacts. The key lies in three concurrent factors: (1) the high frequency of use of these devices per overnight guest, (2) the interdependence between water consumption and energy

consumption in the DHW subsystem, and (3) the low unit cost of the efficient devices relative to the marginal saving they generate per use event.

Likewise, the need to integrate the analytical measurement of costs with intelligent-automation and artificial-intelligence tools is highlighted. The incorporation of IoT (Internet of Things) sensors for real-time flow telemetry makes it possible to detect invisible leaks in toilets and unusual fluctuations in the pressure of hot-water pipes, ensuring that the projected theoretical savings are sustained continuously within the hotel's budget structure (IDAE, 2001). Modern BMS systems, which integrate climate control, lighting, DHW, and security, can generate additional savings of 15% to 25% over point-specific efficiency measures.

From the perspective of strategic cost management, the results suggest that hotel financial management should adopt a proactive approach to efficiency investment instead of the traditional reactive approach of cost reduction during crises. The demonstration that marginal investments in low-flow devices generate savings more than ten times their cost in a single year should drive the systematic incorporation of these projects into annual maintenance and operating budgets, even in periods of tariff normality.

In the Latin American context, the applicability of the model extends beyond the Chilean case. The tariff structure and water-scarcity conditions are similar across broad regions of Peru, Colombia, Mexico, and Argentina, where hotels face growing regulatory pressures regarding the efficient use of water and energy. The transferability of the method lies in its parametric nature: by substituting the input variables (local tariffs, use patterns, number of rooms), the model produces specific results for any lodging establishment in any geographical context.

Nevertheless, it is important to acknowledge the limitations of the study. The model assumes average use patterns that may vary significantly among different types of guests (vacation tourists versus business travelers) and among seasons. The empirical validation is limited to a single case study, which restricts the statistical generalization of the results, although not their conceptual validity. Future research should expand the sample to multiple establishments and validate the use assumptions through direct measurement with flow sensors.

Another relevant limitation concerns the absence of an exhaustive sensitivity analysis regarding variations in water and energy tariffs. Although the model can easily incorporate different tariff scenarios, the case study presented uses average tariffs that may not reflect regional variability or the specific conditions of each sanitary concession. Future research should incorporate probability distributions for tariffs and use patterns, transforming the deterministic model into a stochastic model that captures the uncertainty inherent in the crisis context.

6. CONCLUSIONS

The analytical cost-management model for energy and water consumption developed in this work proves to be a rigorous, transferable, and highly effective tool for financial decision-making in the

lodging industry in contexts of volatility and crisis. The main conclusions of the study are as follows:

First, the replacement of traditional taps with low-flow technological control devices (aerators and aerated shower handsets) reduces the total water consumption in the rooms of a medium-sized hotel by 46.9%, with an investment that is recovered in less than 40 operating days.

Second, the annual economic saving of more than 12 million Chilean pesos makes it possible to amortize the initial investment (CLP 1,222,000) with a highly positive net cash flow throughout the entire useful life of the equipment, generating an NPV of CLP 42,816,643 for a 5-year horizon at a discount rate of 10%.

Third, treating domestic hot water (DHW) as a decoupled and energetically interrelated cost gives financial management real visibility of the marginal variable cost per overnight stay, revealing that the thermal energy saving represents 27.6% of the total saving.

Fourth, the proposed integrated model constitutes an original contribution to the management-control field by formally linking efficiency engineering with analytical cost accounting, overcoming the disciplinary gap that has limited resource management in Latin American hotels.

Finally, lodging enterprises in Chile and Latin America are recommended to adopt analytical resource-accounting methodologies integrated with permanent preventive-maintenance programs and digital IoT instrumentation in order to maximize their operational resilience in the face of supply crises.

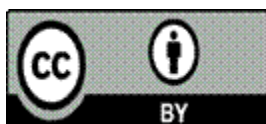
Future research lines include: (a) the extension of the model to the climate-control subsystem (HVAC), which represents between 40% and 50% of hotel energy consumption; (b) the stochastic modeling of use patterns through probability distributions derived from actual measurements; (c) the evaluation of the impact of environmental certifications (LEED, EarthCheck) on the cost structure; and (d) the application of the method to hotel chains with multiple establishments, assessing economies of scale in efficiency investment.

REFERENCES

- Alonso-Almeida, M. M., Rocafort, A., & Borrajo, F. (2017). Sustainability and financial performance in the hotel industry: A dynamic panel data approach. *Journal of Cleaner Production*, 165, 748-756. <https://doi.org/10.1016/j.jclepro.2017.07.147>
- Becken, S., & McLennan, C. L. (2017). Evidence of the water-energy nexus in tourist accommodation. *Journal of Cleaner Production*, 144, 415-425.
- Bohdanowicz, P. (2006). Environmental awareness and initiatives in the Swedish and Polish hotel industries: Survey results. *International Journal of Hospitality Management*, 25(4), 662-682. <https://doi.org/10.1016/j.ijhm.2005.06.006>

- Bohdanowicz, P., Zientara, P., & Novotna, E. (2011). International hotel chains and environmental protection: The case of Hilton's WE CARE program. *Journal of Sustainable Tourism*, 19(7), 797-816. <https://doi.org/10.1080/09669582.2010.549566>
- Cavia-Soto, M., Fernández-Sánchez, P., & López-Sintas, J. (2020). Strategic cost management in hospitality: An activity-based costing approach for resource efficiency. *Tourism Economics*, 26(5), 812-830. <https://doi.org/10.1177/1354816619883554>
- Deng, S. M., & Burnett, J. (2002). Energy use and management in hotels in Hong Kong. *Applied Energy*, 73(3-4), 213-222. [https://doi.org/10.1016/S0306-2619\(02\)00055-8](https://doi.org/10.1016/S0306-2619(02)00055-8)
- Drury, C. (2018). *Management and cost accounting* (10th ed.). Cengage Learning.
- Eurostat. (2021). *Energy, transport and environment statistics: 2021 edition*. Publications Office of the European Union. <https://doi.org/10.2785/4705>
- Gössling, S. (2015). New performance indicators for water management in tourism. *Tourism Management*, 46, 233-244. <https://doi.org/10.1016/j.tourman.2014.06.018>
- Gössling, S., Peeters, P., Hall, C. M., Ceron, J. P., Dubois, G., Lehmann, L. V., & Scott, D. (2012). Tourism and water use: Supply, demand, and security. *Annals of Tourism Research*, 39(1), 1-24. <https://doi.org/10.1016/j.annals.2011.03.015>
- Gössling, S., Scott, D., & Hall, C. M. (2021). Pandemics, tourism and global change: A rapid assessment of COVID-19. *Journal of Sustainable Tourism*, 29(1), 1-21. <https://doi.org/10.1080/09669582.2020.1758708>
- Hansen, D. R., & Mowen, M. M. (2021). *Cost management: Accounting and control* (9th ed.). Cengage Learning.
- Hoff, H. (2011). *Understanding the nexus: Background paper for the Bonn 2011 Nexus Conference*. Stockholm Environment Institute.
- Institute for the Diversification and Saving of Energy [IDAE]. (2001). *Ahorro de energía en el sector hotelero: Recomendaciones y soluciones de bajo riesgo* [Energy saving in the hotel sector: Low-risk recommendations and solutions] (M-3861-2001). IDAE, General Secretariat of Tourism.
- Kaplan, R. S., & Norton, D. P. (2004). *Strategy maps: Converting intangible assets into tangible outcomes*. Harvard Business Press.
- Ministry of Energy of Chile. (2023). *Balance energético nacional 2022-2023* [National energy balance 2022-2023]. Government of Chile.
- Molina-Azorín, J. F., Tarí, J. J., Pereira-Moliner, J., López-Gamero, M. D., & Pertusa-Ortega, E. M. (2015). The effects of quality and environmental management on competitive

- advantage: A study in the hotel industry. *International Journal of Hospitality Management*, 50, 41-54. <https://doi.org/10.1016/j.ijhm.2015.07.008>
- Pinto, A., Afonso, A. S., Santos, A. S., Pimentel-Rodrigues, C., & Rodrigues, F. (2017). Nexus water energy for hotel sector efficiency. *Energy Procedia*, 111, 215-225.
- Shank, J. K., & Govindarajan, V. (1993). *Strategic cost management: The new tool for competitive advantage*. Free Press.
- Sampaio, C., Sebastião, J. R., & Farinha, L. (2024). Hospitality and tourism demand: Exploring industry shifts, themes, and trends. *Societies*, 14(10), 207.
- Superintendency of Sanitary Services. (2023). *Informe anual de tarifas de servicios sanitarios 2022-2023* [Annual report on sanitary service tariffs 2022-2023]. Government of Chile.
- World Bank. (2020). *Chile: Gestión del recurso hídrico para un desarrollo sostenible* [Chile: Water resource management for sustainable development]. World Bank Group.
- United Nation Tourism. (2022). *Hotel energy solutions: Fostering innovation and energy efficiency in the hotel sector*. UNWTO Publications. <https://doi.org/10.18111/9789284414154>



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