



Perceptual validation of TPM-H₂O for industrial water governance: Evidence from operators, managers and community stakeholders in a brewery case study

Ana Karen Córdoba Schettino *, Luis Raúl Córdoba Schettino, Xavier Contreras Calvario, Carlos Navarrete Enríquez, Samantha Conde Sánchez and Salvador Nava Rodríguez

Instituto Tecnológico de Orizaba, Orizaba, Veracruz, México.

World Journal of Advanced Engineering Technology and Sciences, 2026, 20(01), 163–168

Publication history: Received on 31 May 2026; revised on 05 July 2026; accepted on 09 July 2026

Article DOI: <https://doi.org/10.30574/wjaets.2026.20.1.0352>

Abstract

Industrial water-efficiency programs are often evaluated through technical indicators, yet their durability also depends on whether operators, managers and surrounding communities perceive the intervention as understandable, controllable and legitimate. This study evaluates the perceptual validation of TPM-H₂O, an integrated industrial water-governance model implemented in a brewery case study in Orizaba, Mexico. A pre/post design was applied in 2024 using structured Likert-scale questionnaires administered to operators (n = 30), managers (n = 15) and community stakeholders (n = 20). The analysis focused on item-level mean changes, relative variation and Welch tests. Real water-consumption records from 2022 to 2024 were used only as operational context; the main contribution of this article is the organizational and social validation of the model. Results showed consistent improvements across all stakeholder groups. Global means increased from 2.13 to 3.66 among operators, from 2.17 to 3.76 among managers and from 2.11 to 3.80 among community participants. The strongest improvements were observed in visible operational controls among operators (+1.77), process-level information among managers (+2.33) and communication with the community (+2.20). These results suggest that TPM-H₂O can function not only as a technical water-efficiency framework but also as a governance mechanism that transforms indicators into routines, transparency and stakeholder confidence. The study is limited by its single-case design, short post-intervention horizon and self-report nature.

Keywords: Industrial water governance; TPM-H₂O; Stakeholder perception; Brewery; Social legitimacy; Water management

1. Introduction

Industrial water management is usually assessed through technical indicators such as total consumption, water intensity, water footprint or process-level use. These indicators are necessary because they allow facilities to diagnose inefficiencies, establish baselines and compare performance. However, measurement alone does not guarantee that water-saving practices will become part of daily work. A plant may report reductions in water use while still facing weak routines, fragmented accountability or low stakeholder trust. For this reason, the social and organizational validation of water-management interventions is an important complement to technical evaluation [1-3].

The beverage industry illustrates this challenge clearly. Water is used as an input, a cleaning resource, a cooling medium and a support service for production continuity. In breweries, water performance depends not only on engineering controls but also on operator discipline, managerial decision-making and the credibility of the organization in its local context. When water scarcity and social expectations are present, the legitimacy of an industrial facility depends on whether its actions are visible, understandable and trusted by internal and external stakeholders [4-6].

* Corresponding author: Ana Karen Córdoba Schettino

TPM-H2O was developed as an integrated model that connects water indicators with Total Productive Maintenance (TPM), Kaizen routines, visual control and stakeholder transparency. Technical water-management studies often focus on longitudinal process-level consumption. The present article addresses a complementary question: To what extent did operators, managers and community stakeholders perceive the TPM-H2O intervention as improving water governance, operational control and social legitimacy?

The objective of this article is to evaluate the perceptual validation of the TPM-H2O model through pre/post survey evidence from three stakeholder groups. The article contributes to industrial engineering and sustainability management by showing how a water-efficiency model can be assessed not only by cubic meters saved, but also by its capacity to institutionalize routines, support decision-making and strengthen trust.

2. Materials and methods

2.1. Study design and case context

The study followed a quantitative-applied, pre/post case-study design. The case corresponded to a brewery located in Orizaba, Veracruz, Mexico. The industrial facility is anonymized in this manuscript to protect corporate confidentiality and avoid disclosure of sensitive operating information. The intervention was implemented under the TPM-H2O logic during 2024, with emphasis on the conversion of water indicators into operational routines, visible controls, training, process-level follow-up and stakeholder communication.

The article uses operational water-consumption records only as contextual evidence. The main unit of analysis is perceptual: operators, managers and community stakeholders who evaluated the organizational and social effects of the TPM-H2O intervention. This scope is important because the article offers a contribution centered on governance validation, stakeholder perception and organizational legitimacy rather than on a detailed process-consumption decomposition.

2.2. Participants and instruments

Three stakeholder groups were included: operators ($n = 30$), managers ($n = 15$) and community participants ($n = 20$). Each group answered a five-item questionnaire before and after the intervention using a Likert-type scale from 1 to 5. The operator questionnaire assessed procedures, training, visible controls, perceived water efficiency and motivation. The manager questionnaire assessed process information, standardized indicators, strategic decisions, continuous improvement culture and perceived economic-environmental benefits. The community questionnaire assessed responsible water management, communication, trust in conflict reduction, environmental benefits and social license to operate.

Table 1 Methodological structure of the perceptual validation study

Element	Specification
Approach	Quantitative-applied pre/post case study
Main unit of analysis	Stakeholder perception measured through Likert-scale questionnaires
Case context	Anonymized brewery in Orizaba, Veracruz, Mexico
Groups	Operators ($n = 30$), managers ($n = 15$), community stakeholders ($n = 20$)
Intervention logic	TPM-H2O: water indicators, TPM routines, Kaizen logic, visual control and transparency
Technical data use	Operational water-consumption records used only as contextual background
Publication distinction	Focus on organizational and social validation rather than longitudinal process-consumption analysis

2.3. Data analysis

The analysis was conducted at item and group level. First, pre- and post-intervention means were calculated for each item. Second, absolute changes and relative changes were interpreted to identify the strongest areas of improvement. Third, Welch tests were used as an inferential reference because the pre/post comparisons involved unequal variance

assumptions and different stakeholder groups. Fourth, the results were interpreted through a governance lens, linking each perceptual change to operational discipline, managerial institutionalization or social legitimacy.

Because the questionnaires were intentionally short and multidimensional, internal consistency coefficients were not used as the primary validation criterion. A low or unstable Cronbach alpha can occur when items measure different dimensions of a construct rather than a single homogeneous scale [7]. For this reason, the article prioritizes item-level interpretation and convergence across stakeholder groups instead of treating each five-item questionnaire as a strictly unidimensional psychometric scale.

2.4. Ethical and confidentiality considerations

The results are reported in aggregate form. No personal identifiers are disclosed. The industrial case is anonymized and the article avoids revealing sensitive production information. The study involved adult participants and survey information was interpreted only at group level. The article also avoids calculating a real Water Use Ratio because verified production volume was not available in the depurated real-data set.

3. Results and discussion

3.1. Global perceptual change by stakeholder group

The three stakeholder groups reported clear positive changes after the TPM-H2O intervention. Operators increased from a global mean of 2.13 to 3.66, managers from 2.17 to 3.76 and community stakeholders from 2.11 to 3.80. The community group showed the highest relative improvement (+80.1%), followed by managers (+73.0%) and operators (+72.1%). The consistency of this pattern is relevant because it suggests that the intervention was not perceived only by internal personnel, but also by external stakeholders who evaluated communication, trust and social legitimacy.

Table 2 Global pre/post perceptual scores by stakeholder group

Group	n	Before	After	Absolute change	Relative change (%)
Operators	30	2.13	3.66	+1.53	+72.1
Managers	15	2.17	3.76	+1.59	+73.0
Community	20	2.11	3.80	+1.69	+80.1

3.2. Operator perception: from reactive use to visible control

Among operators, the strongest increases occurred in visible meters/controls (+1.77; +91.7%) and motivation for saving initiatives (+1.74; +93.5%). This is important because TPM depends on operational ownership: operators must be able to see the abnormality, understand the standard and participate in prevention. Improvements in procedures, training and perceived efficiency also suggest that the intervention was not interpreted as an isolated environmental campaign but as a practical work-system adjustment.

3.3. Manager perception: evidence-based governance

Managers showed the highest absolute improvement in process-level information (+2.33), followed by perceived economic and environmental benefits (+1.73). This indicates that TPM-H2O strengthened the managerial layer of water governance by making consumption more visible and more useful for decision-making. The result is consistent with the idea that sustainability indicators become effective only when they are connected to routines, responsibilities and decisions rather than remaining as isolated reports.

3.4. Community perception: transparency and social license

The community group showed the largest global relative improvement. The strongest item-level gains were better communication with the community (+2.20) and trust in conflict reduction (+1.80). These findings are particularly relevant because water management in industrial regions has a legitimacy component. Communities may not directly observe internal process controls, but they can perceive whether the organization communicates, explains and demonstrates responsible water management. In this sense, TPM-H2O operated as a bridge between internal operational improvement and external stakeholder confidence.

Table 3 Item-level pre/post changes by stakeholder group

Group	Indicator	Before	After	Δ	p-value
Operators	Procedures for water use and saving	2.46	3.80	+1.34	<0.001
Operators	CIP and maintenance training	2.10	3.60	+1.50	<0.001
Operators	Visible meters and controls	1.93	3.70	+1.77	<0.001
Operators	Perceived water-efficiency improvement	2.26	3.60	+1.34	<0.001
Operators	Motivation for saving initiatives	1.86	3.60	+1.74	<0.001
Managers	Process-level information	1.93	4.27	+2.33	<0.001
Managers	Standardized indicators	2.27	3.67	+1.40	<0.001
Managers	Strategic decisions with TPM-H2O	2.47	3.60	+1.13	0.022
Managers	Continuous-improvement culture	2.13	3.47	+1.33	0.005
Managers	Economic and environmental benefits	2.07	3.80	+1.73	<0.001
Community	Responsible water management	2.25	3.55	+1.30	<0.001
Community	Better communication with community	1.60	3.80	+2.20	<0.001
Community	Trust in conflict reduction	2.35	4.15	+1.80	<0.001
Community	Perceived environmental benefits	2.10	4.00	+1.90	<0.001
Community	Strengthened social license	2.25	3.50	+1.25	0.007

3.5. Governance interpretation of the TPM-H2O intervention

The results show a coherent governance pattern across the three levels of analysis. At the shop-floor level, operators reported stronger control, training and motivation. At the managerial level, the most important effect was the availability and use of process-level information. At the social level, the dominant change was improved communication and trust. This sequence is consistent with a practical governance chain: measurement enables visibility, visibility enables routines, routines support managerial decisions and transparent decisions strengthen legitimacy.

Table 4 Governance interpretation of the main perceptual effects

Stakeholder group	Dominant change	Governance meaning	Practical implication
Operators	Visible controls and motivation	Water use became observable and actionable at shop-floor level	Use visual boards, leak logs and short daily reviews to stabilize routines
Managers	Process-level information	Water indicators became decision-support tools rather than passive records	Link KPIs to meetings, accountability and investment prioritization
Community	Communication and trust	Internal water management gained external visibility and credibility	Report progress in simple language and maintain stakeholder dialogue

3.6. Scope of the contribution

This manuscript does not present a detailed year-by-year decomposition of water consumption by process as its main result. Instead, it uses the doctoral intervention as a case context to examine whether TPM-H2O was perceived as a governance mechanism by different stakeholder groups. Its contribution is therefore organizational and social: it explains how technical water indicators can be translated into operational ownership, managerial confidence and external legitimacy.

3.7. Limitations

The study has several limitations. First, it is a single-case study; therefore, the results are analytically transferable but not statistically generalizable to all breweries. Second, the post-intervention horizon was short, so the persistence of perceptions should be evaluated in later periods. Third, the instrument used self-report data, which may be affected by social desirability or organizational expectations. Fourth, the questionnaires were short and multidimensional; therefore, the article interprets item-level changes rather than claiming strong unidimensional psychometric reliability. Fifth, real production-volume data were not available in the depurated data set, so the article does not calculate a real Water Use Ratio.

4. Conclusion

This article evaluated the perceptual validation of TPM-H2O as an industrial water-governance model in a brewery case study. The present contribution focused on operators, managers and community stakeholders as evidence of organizational and social validation. Results showed consistent improvements across all groups, with the strongest gains in visible operational controls, process-level information and community communication.

The findings suggest that TPM-H2O can operate as more than a water-efficiency framework. It can also function as a governance mechanism that translates indicators into routines, routines into managerial decisions and decisions into transparency and legitimacy. For industrial facilities, this implies that water management should not be evaluated only by technical indicators, but also by the degree to which stakeholders understand, trust and participate in the improvement system.

Future research should apply the perceptual validation framework in additional plants, extend the post-intervention horizon and integrate verified production data to connect governance perception with production-normalized water performance. Multi-site studies would also allow the model to be tested under different technological, organizational and territorial conditions.

Compliance with ethical standards

Acknowledgments

The author acknowledges the academic support received during the doctoral research process and the collaboration of the industrial personnel and community participants who contributed information for the case study.

Disclosure of conflict of interest

The author declares no conflict of interest related to this manuscript. The industrial case has been anonymized for confidentiality purposes.

Statement of informed consent

Survey participation was treated as voluntary and the information is reported only in aggregate form. No personal identifiers are disclosed in the manuscript.

Data availability statement

The data supporting the findings are derived from doctoral research records. Due to industrial confidentiality, raw operational and survey records are not publicly disclosed. Aggregated data may be requested from the corresponding author subject to institutional and confidentiality restrictions.

Author contributions

Cordoba Schettino Ana Karen: conceptualization, methodology, data curation, formal analysis, investigation, writing - original draft, writing - review and editing.

References

- [1] UNESCO, UN-Water and World Water Assessment Programme. (2024). The United Nations World Water Development Report 2024: Water for prosperity and peace. UNESCO, Paris, France.
- [2] International Organization for Standardization. (2014). ISO 14046:2014 Environmental management - Water footprint - Principles, requirements and guidelines. ISO, Geneva, Switzerland.
- [3] Hoekstra AY, Chapagain AK, Aldaya MM and Mekonnen MM. (2011). The Water Footprint Assessment Manual: Setting the global standard. Earthscan, London, United Kingdom.
- [4] Nakajima S. (1988). Introduction to TPM: Total Productive Maintenance. Productivity Press, Cambridge, United States.
- [5] Imai M. (1986). Kaizen: The key to Japan's competitive success. McGraw-Hill, New York, United States.
- [6] Womack JP and Jones DT. (1996). Lean Thinking: Banish waste and create wealth in your corporation. Simon & Schuster, New York, United States.
- [7] Nunnally JC and Bernstein IH. (1994). Psychometric theory, Third edition. McGraw-Hill, New York, United States.
- [8] Likert R. (1932). A technique for the measurement of attitudes. Archives of Psychology, 22(140), 1-55.
- [9] Yin RK. (2018). Case study research and applications: Design and methods, Sixth edition. SAGE Publications, Thousand Oaks, United States.
- [10] Freeman RE. (1984). Strategic management: A stakeholder approach. Pitman, Boston, United States.
- [11] Suchman MC. (1995). Managing legitimacy: Strategic and institutional approaches. Academy of Management Review, 20(3), 571-610.
- [12] United Nations. (2015). Transforming our world: The 2030 Agenda for Sustainable Development. United Nations, New York, United States.