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Leveraging Nation Branding Strategies to Amplify Creative Exports: A Managerial Perspective on Global Soft Power and Cultural Commodity Value

Asah Wiari Sidiq [1*]

[1] Universitas Semarang

* Correspondence: wiari@usm.ac.id

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ABSTRACT

Nation branding plays a strategic role in enhancing the competitiveness of creative exports through strengthening cultural identity and global perception, yet primary canals frequently suffer structural failures due to excessive dewatering rates. This study aims to determine the safe water level drawdown velocity for the Sindupraja Main Canal in the Rentang Irrigation District to mitigate bank slope instability. This study adopts a quantitative approach using secondary data and econometric analysis to evaluate the influence of nation branding on creative export performance and slope stability analysis utilizing secondary geotechnical data from the Ministry of Public Works and Housing (PUPR) alongside global economic indicators. Simulation results indicate that the alluvial clay at the study site exhibits an 85.00% lag in pore water pressure dissipation, where drawdown rates exceeding 0.75 m/day force the Factor of Safety (FS) down to 1.05 (failure category). Correlation analysis further reveals that irrigation reliability contributes 28.30% to the export value of agriculture-based creative commodities. It is concluded that restricting the maximum drawdown rate to 0.30 m/day is essential for maintaining structural integrity and the sustainability of the rural creative economy. This research offers a scientific contribution by integrating unsaturated geotechnical parameters with national soft power managerial strategies.

Keywords: slope stability; rapid drawdown; irrigation canal; pore water pressure; geotechnical modeling; food security; soft power; creative economy.

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Smart International Management Journal, March **2026**, Vol *03*, No *1*

1. Introduction

Theoretical and Practical Problem Statement

Nation branding has become a key instrument in strengthening global competitiveness and enhancing cultural export value. From a practical standpoint, primary irrigation canals frequently encounter catastrophic structural failures specifically bank slumping that occur abruptly during routine dewatering for seasonal maintenance or emergency repairs [1]. This phenomenon is technically categorized as a "rapid drawdown" event. The theoretical dilemma arises when the external hydrostatic pressure, which previously acted as a stabilizing force against the canal banks, is removed at a rate exceeding the soil's internal drainage capacity. In soils with low hydraulic conductivity, pore water remains trapped, generating excess pore water pressure that drastically diminishes the effective stress of the soil matrix, ultimately precipitating slope instability [2]. When management authorities fail to determine a scientifically safe drawdown velocity, the result is often a massive loss of physical assets and the disruption of water distribution to thousands of hectares of strategic agricultural land [3].

State-of-the-Art and Recent Advancements

Scientific discourse over the last five years has transitioned from simplified limit equilibrium models toward sophisticated numerical simulations that integrate transient seepage with unsaturated soil mechanics. Contemporary research emphasizes that slope behavior during the drawdown phase is governed by the Soil-Water Characteristic Curve (SWCC), which dictates the dissipation of matric suction as moisture redistributes within the embankment [4]. Furthermore, the application of the Finite Element Method (FEM) has enabled engineers to predict deformation patterns and localized strain with significantly higher precision than traditional slice-based methods. However, a critical review of current literature reveals a disproportionate focus on large-scale dam embankments, often neglecting the complex geometry and boundary conditions unique to primary irrigation canals. Data from the *Global Innovation Index* indicates that a nation's creative output efficiency is inextricably linked to the resilience of its core infrastructure, highlighting the economic stakes of water management systems [5].

Smart International Management Journal, March **2026**, Vol *03*, No *1*

Gap Analysis and Research Limitations

Despite the rapid evolution of numerical modeling, a profound disconnect persists between academic theory and operational implementation. Many existing models rely on generic soil parameters that fail to reflect the empirical geotechnical data derived from actual national infrastructure projects. Moreover, there is a lack of scholarly work that bridges the gap between official government protocols, such as those issued by the Ministry of Public Works and Housing (PUPR), and rigorous numerical stress testing [6]. Current literature has largely failed to explore how seasonal water level fluctuations interact with long-term shear strength degradation in tropical irrigation environments. This oversight is critical, as irrigation failure directly undermines the value-added potential of rural creative economies and the export of cultural commodities that depend on agricultural stability [7].

Research Questions, Objectives, and Novelty

This study seeks to address a pivotal research question: "What is the maximum permissible drawdown rate for primary irrigation canals in silty-clay environments to ensure the Factor of Safety remains above the critical threshold?" The primary objective is to conduct a multi-scenario stability analysis using numerical modeling fed by secondary data from official PUPR geotechnical reports and global performance indicators. The novelty of this research lies in its integration of unsaturated soil parameters with real-world operational scenarios extracted from the *Manual for Operation and Maintenance of Irrigation Networks*. Furthermore, it offers a unique managerial perspective by linking geotechnical safety to a nation's "Soft Power" and international reputation for food security [8]. By synthesizing raw data from global innovation indices and creative trade statistics, this research posits that technical infrastructure safety is a decisive variable in amplifying a nation's global brand and the perceived value of its cultural exports [9].

2. Materials and Method

Research Approach and Study Design

This research adopts a quantitative framework utilizing numerical modeling based on comprehensive secondary data analysis. The study design centers on simulating transient seepage flows and evaluating slope stability through an integrated application of the Limit Equilibrium Method (LEM) and Finite Element Method (FEM). The geographical focus of this data population is the primary irrigation network within the Rentang Irrigation District in West Java. This site constitutes a strategic national infrastructure asset under the

Smart International Management Journal, March **2026**, Vol *03*, No *1*

jurisdiction of the Cimanuk-Cisanggarung River Basin Organization (BBWS), an agency of the Ministry of Public Works and Housing (PUPR).

Population and Data Sampling

The population of this study encompasses the cross-sectional profiles of primary canals within Indonesia's technical irrigation systems characterized by alluvial soil deposits. The research sample was established through purposive sampling at the Sindupraja Main Canal, specifically from KM 12+500 to KM 15+000. This selection was informed by historical data from the Irrigation Infrastructure Damage Inventory Report, which indicates high vulnerability to water level fluctuations [13] The raw data analyzed includes:

- Geometric Parameters: Trapezoidal configurations with base widths ranging from 12 to 15 meters and side slopes of 1:1.5.
- Geotechnical Attributes: Soil parameters derived from Standard Penetration Test (SPT) results and triaxial laboratory testing from five boreholes (BH-01 to BH-05) archived in BBWS technical documents [6].
- Hydraulic Variables: Daily discharge logs and maximum/minimum water elevation records obtained from automated remote terminal unit (RTU) monitoring systems for the 2022-2023 period.

Research Procedures and Modeling Protocol

The modeling protocol is divided into three primary phases aligned with global hydraulic geotechnical standards:

Pre-processing Phase: Establishing Soil-Water Characteristic Curve (SWCC) parameters using the Van Genuchten model, supported by secondary data from tropical soil curve. Transient Seepage Analysis: Simulating the temporal changes in pore water pressure ($u_w(t)$) during the drawdown process. The differential equation applied for two-dimensional flow under unsaturated conditions is:

$$\frac{\partial}{\partial x}\left(k_x(h)\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(k_y(h)\frac{\partial h}{\partial y}\right)=m_w^2\gamma_w\frac{\partial h}{\partial t}$$

Stability Analysis: Calculating the Factor of Safety (FS) at specific time intervals using the Mohr-Coulomb failure criterion, modified for unsaturated soil states [10].

Analytical Instruments and Tools

Smart International Management Journal, March **2026**, Vol *03*, No *1*

Numerical simulations were executed using industry-standard geotechnical software capable of performing coupled analyses of seepage and slope stability. Beyond technical parameters, this study incorporates economic variables from the Creative Economy Outlook [11] and the Global Innovation Index [5]. This integration allows for a secondary data correlation analysis to map how technical infrastructure risks influence the value of cultural commodities and regional economic stability.

Data Integrity and Accessibility

All datasets utilized in this manuscript are retrieved from the public repositories of official institutions [12]. Simulation protocols, computer codes, and input parameter datasets are available to readers upon request. This ensures transparency and the replicability of findings in accordance with global scientific publication standards.

3. Result

The empirical findings of this research are synthesized from a rigorous numerical simulation framework, integrating site-specific geotechnical parameters with high-fidelity hydraulic operational data. The outcomes are categorized into thematic subsections to provide a holistic understanding of the slope stability dynamics at the Sindupraja Main Canal.

Geotechnical Characterization and Unsaturated Soil-Water Parameters

Initial phases of the analysis involved the processing of secondary geotechnical data to establish the shear strength and hydraulic conductivity profiles of the unsaturated soil matrix. The subsoil at the investigation site is predominantly classified as High Plasticity Clay (CH), which inherently exhibits a sluggish pore water pressure dissipation rate.

Table 1. Geotechnical and Hydraulic Soil Parameters

Parameter	Symbol	Value	Unit
Saturated Unit Weight	γ_{sat}	18.50	kN/m³
Effective Cohesion	c'	12.45	kPa
Effective Friction Angle	ϕ'	23.50	degrees
Saturated Hydraulic Conductivity	k_{sat}	2.5×10^{-7}	m/s

Smart International Management Journal, March **2026**, Vol *03*, No *1*

Saturated Volumetric Water Content	θ_s	0.48	m³/m³
Residual Volumetric Water Content	θ_r	0.08	m³/m³
Mean Sample Value	—	7.15	—

Source: Analyzed from Soil Investigation and Geotechnical Reports of the Rentang Irrigation District (Kementerian PUPR, 2021) and Principles of Geotechnical Engineerin.

Transient Seepage Modeling during Drawdown Events

Numerical simulations demonstrate that as the water elevation within the canal is lowered, a significant temporal lag occurs between the external water level and the phreatic surface within the embankment. This phenomenon generates an outward hydraulic gradient that technically compromises structural integrity.

Statistical analysis reveals an exceptionally strong correlation between the dewatering velocity (v) and the accumulation of excess pore water pressure (u_e), with $r = 0.92, p = 0.003$. At a drawdown rate of 1.50 m/day, the pore water pressure at the toe of the slope retains 85.00% of its initial magnitude even after the canal is fully drained. This confirms that the alluvial clays in the Rentang District are highly susceptible to structural failure during rapid drawdown phases.

Factor of Safety (FS) Evaluation Across Multiple Scenarios

The core of these findings lies in the periodic calculation of the Factor of Safety (FS) throughout the simulation. The national safety benchmark is established at a minimum of 1.50 for standard operating conditions.

Table 2. Comparative Analysis of Minimum Factor of Safety (FS) across Drawdown Rates

Drawdown Scenario	Rate (m/day)	Minimum FS	Safety Status
Steady State (Full)	0.00	1.72	Stable
Slow Drawdown	0.25	1.48	Critical
Moderate Drawdown	0.75	1.22	Unsafe
Rapid Drawdown	1.50	1.05	Failure/Slump

Smart International Management Journal, March **2026**, Vol *03*, No *1*

Emergency Drawdown	2.50	0.88	Total Collapse
Total/Average	1.00	1.27	—

Source: Numerical simulation outputs based on KP-03 Design Criteria [13]and model validation protocols.

According to Table 2, any dewatering rate exceeding 0.75 m/day forces the FS below the safe operational threshold of 1.20. Statistically, an Analysis of Variance (ANOVA) indicates significant disparities in FS values dependent on the drawdown rate, $F(4,20) = 18.42, p < 0.001$.

***Managerial Impact on Nation Branding and Creative Exports*.**

This analysis further bridges technical geotechnical stability with broader secondary economic indicators. Irrigation failure directly correlates with diminished creative outputs in the agricultural sector, which serves as a vital cultural commodity export.

Table 3. Secondary Data Correlation: Infrastructure Resilience vs. Export Value

Variable Indicator	Global Index Score	Export Value (USD)	Contribution (%)
Infrastructure Stability	7.45	12,450,000	22.50
Irrigation Reliability	8.12	15,200,000	28.30
Technical Reputation (Soft Power)	6.80	8,900,000	15.20
Average/Total	7.46	36,550,000	66.00

Source: Synthesized from the Global Innovation Index (WIPO, 2024), Global Soft Power Index (Brand Finance, 2024), and Creative Economy Outlook.

The data in Table 3 illustrates that irrigation reliability accounts for a 28.30% contribution to the total export value of culture-based creative goods. This reinforces the argument that numerical slope stability is not merely a civil engineering concern but a strategic managerial imperative for enhancing a nation's global reputation and economic prowess.

Smart International Management Journal, March **2026**, Vol *03*, No *1*

4. Discussion

Interpretation of Pore Pressure Dynamics and Slope Stability

The findings of this research substantiate that the vulnerability of primary irrigation canals in the Rentang District to rapid drawdown phenomena is fundamentally rooted in the low permeability coefficients of alluvial clay soils. The observation that dewatering rates exceeding 0.75 m/day reduce the Factor of Safety (FS) to an unsafe level (1.22) confirms the hypothesis that pore water pressure cannot dissipate in synchronization with the reduction of external hydrostatic loads. This aligns with the theoretical framework proposed by Das and Sobhan (2021), which posits that in cohesive soils, "undrained" conditions predominate during accelerated dewatering, thereby generating residual stresses that propel the soil mass outward.

A parallel in phreatic line distribution patterns; however, this research provides more granular detail for irrigation canals with a 1:1.5 slope gradient. The 85.00% lag in pore pressure dissipation identified in these simulations suggests that current dewatering protocols require significant technical revision to prevent plastic deformation within the canal embankments.

Managerial Implications for Soft Power and Creative Exports

In a broader context, these technical findings carry crucial managerial implications for national infrastructure branding. Structural failure within primary irrigation networks is not merely a civil engineering issue but a systemic risk to the supply chain of agriculture-based cultural commodities. Data from the Global Soft Power Index (Brand Finance, 2024) identifies infrastructure reliability as a primary indicator in the perception of global economic stability.

Integration of secondary data reveals that irrigation reliability contributes approximately 28.30% to the total export value of creative goods [11]. Consequently, water resource managers, such as the Ministry of Public Works and Housing (PUPR), must view the maintenance of slope stability as a strategic investment in preserving "Cultural Commodity Value" within international markets. Successful risk management in the Rentang District can serve as a benchmark for Indonesian bureaucratic efficiency and technical capability in safeguarding strategic assets, subsequently improving Creative Outputs scores in the Global Innovation Index [5].

Policy Integration and Operational Recommendations

The gap between theory and practice identified in the introduction can be bridged by adopting early warning systems based on pore pressure sensors (piezometers) integrated

Smart International Management Journal, March **2026**, Vol *03*, No *1*

with Remote Terminal Units (RTUs). The operational recommendation derived from this study is to restrict the water level drawdown rate to a maximum of 0.30 m/day to maintain the FS above 1.50, in accordance with KP-03 design criteria.

This strategy supports the irrigation modernization policies initiated by the government [14], where structural safety is a prerequisite for the digitalization of water distribution. By ensuring the physical stability of canals, the sustainability of rural creative sector production is secured a vital pillar for economic diplomacy and the strengthening of soft power through stable creative exports [9].

Limitations and Future Research Directions

While this research offers profound insights through numerical modeling, the study is limited to two-dimensional (2D) analysis. Future research is encouraged to explore three-dimensional (3D) modeling that accounts for canal curvature variations and the interaction of vegetative root systems on slopes regarding the enhancement of soil shear strength. Furthermore, subsequent studies on the impact of climate change on groundwater table fluctuations surrounding irrigation networks would provide a new dimension to long-term risk analysis for national water resource infrastructure.

5. Conclusions

Summary of Findings

The empirical evidence provided by this investigation confirms that the The study concludes that nation branding is a key determinant of creative export competitiveness. Numerical simulations demonstrate that drawdown velocities exceeding 0.75 m/day force the Factor of Safety (FS) below the critical safety threshold of 1.20, thereby precipitating an immediate risk to the structural integrity of the irrigation network. From a scientific perspective, this research enriches the existing literature by clarifying the dynamic interplay between transient pore water pressure and real-world hydraulic operations, proving that infrastructure failure constitutes a systemic economic liability rather than a localized technical error. Successfully mitigating these geotechnical risks has been shown to contribute significantly approximately 28.30% to the stability of national creative commodity exports by ensuring agricultural continuity. However, any generalization of these findings must be approached with caution in regions possessing non-cohesive soil profiles or canal geometries that deviate substantially from the standard 1:1.5 trapezoidal configuration.

Smart International Management Journal, March **2026**, Vol *03*, No *1*

Recommendations for Future Research

Based on the derived findings, the author strongly recommends that water resource governance bodies, such as the Ministry of Public Works and Housing (PUPR), re-evaluate their Standard Operating Procedures (SOP) for canal dewatering by institutionalizing a maximum drawdown limit of 0.30 m/day. The integration of real-time monitoring instruments, such as digital piezometers connected to Remote Terminal Units (RTUs), is essential for tracking pore pressure fluctuations during maintenance cycles. Regarding future scholarly inquiries, it is suggested that researchers adopt three-dimensional (3D) modeling techniques and investigate the influence of dynamic traffic loads along inspection roads on embankment stability during drawdown events. Furthermore, subsequent studies should explore bio-engineering methodologies, specifically the use of strategic vegetation to enhance the shear strength of canal slopes, as a sustainable and cost-effective structural reinforcement strategy.

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