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# Modeling ESG-Driven Sustainability Performance in the Steel Industry: Empirical Evidence from Thailand's EEC

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***Abstract***

*Sustainability has become a critical priority for organizations worldwide, particularly in high-impact industries such as steel manufacturing. This study develops and validates a comprehensive measurement model for Environmental, Social, and Governance (ESG)-based sustainability performance in the steel sector. Using survey data from executives of steel manufacturing plants in Thailand's Eastern Economic Corridor (EEC), the study applies Confirmatory Factor Analysis (CFA) and second-order modeling to examine the hierarchical structure of ESG dimensions. The model comprises of 45 indicators across 15 first-order constructs, grouped under three second-order ESG categories. Results confirm the robustness of the model, demonstrating strong validity and reliability across ESG constructs. The findings offer critical insights for policy-makers, corporate leaders, and sustainability practitioners in designing strategic interventions that align with global sustainability goals and industry-specific challenges.*

***Keywords:*** *Sustainability Measurement, ESG Framework, Steel Industry, Structural Equation Modeling, Thailand; Sustainable Development Goals.*

## Introduction

In the modern era, sustainability has emerged as a central goal for organizations, societies, and nations worldwide. This is due to the pressing challenges of environmental degradation, social inequality, and economic imbalance, which adversely affect human quality of life and long-term sustainable development (United Nations, 2023). Which aligns with the United Nations Sustainable Development Goals which aim "to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity" (UNDP, 2015). Sustainability measurement is crucial in defining strategies and directions to mitigate negative impacts and promote sustainability across all sectors.

Recent meta-analytical studies have systematically evaluated the measurement and implications of ESG factors. For instance, Friede, Busch, and Bassen (2015) conducted a comprehensive meta-analysis encompassing over 2,000 empirical studies, finding that approximately 90% of them report a relationship between ESG criteria and corporate financial performance (CFP), with the majority indicating a positive correlation. This affirms the relevance of ESG as both a managerial and, a strategic tool in promoting sustainable investment practices. Furthermore, Zhou and Cui (2022) performed a meta-analysis focusing specifically on ESG disclosure and its impact on firm valuation, stakeholder trust, and sustainability performance, suggesting that

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standardized ESG frameworks enhance comparability, transparency, and accountability across industries and regions. Meta-analytic approaches not only consolidate empirical evidence but also provide insights into the heterogeneity of ESG effects across contexts, industries, and measurement tools. This is particularly relevant as organizations strive to align their internal sustainability metrics with global benchmarks such as the Global Reporting Initiative (GRI), the Sustainability Accounting Standards Board (SASB), and the Task Force on Climate-related Financial Disclosures (TCFD). Therefore, the integration of ESG meta-analytical findings into sustainability frameworks can significantly improve the robustness of strategic decision-making, policy formulation, and academic research aimed at advancing sustainable development goals.

The steel industry is one of the most resource-intensive and emission-heavy sectors, contributing significantly to global greenhouse gas (GHG) emissions, energy consumption, and industrial waste (World Steel Association, 2021). Accounting for approximately 7–9% of global $CO_2$ emissions, the sector is a critical focal point in the global effort to transition toward low-carbon and circular economies. The steel production process involves high-temperature furnaces, extensive use of raw materials (such as iron ore and coal), and generates substantial environmental externalities, including air pollution, solid waste, and water contamination. Furthermore, steel is a foundational material for infrastructure, construction, transportation, and manufacturing, making its sustainability performance integral to broader national and industrial development strategies. As sustainability concerns escalate, industries worldwide face increasing pressure from governments, investors, and consumers to adopt sustainable practices that align with ESG principles (Saxena, Senadheera, & Dutta, 2022). In response to global environmental agreements (e.g., the Paris Agreement) and stakeholder demands for responsible corporate behavior, ESG integration has become a strategic imperative for the steel industry. In addition to environmental risks, steel firms also encounter social and governance challenges—ranging from occupational health and safety, labor rights, and community relations, to supply chain transparency and corporate ethics. Given the steel sector's substantial impact on environmental and social ecosystems, developing a comprehensive sustainability measurement model that integrates ESG criteria is crucial. Such a model will help firms assess their sustainability performance, comply with regulatory frameworks, enhance stakeholder trust, and secure long-term competitiveness in an increasingly sustainability-driven marketplace. However, existing sustainability measurement frameworks often fail to capture the multidimensional nature of ESG challenges specific to the steel industry, including industry-specific environmental externalities, regional social impacts, and governance structures within state-owned or multinational enterprises (OECD, 2021). Therefore, there is a compelling need for an empirically validated, industry-specific measurement model that reflects the complex interplay of ESG dimensions in steel production and management practices.

## Literature Review

### Sustainability and the Sustainable Development Goals (SDGs)

Sustainability has become a global priority for countries, organizations, and industries, particularly in response to the United Nations Sustainable Development Goals (SDGs), introduced in 2015. These 17 provide a strategic framework aimed at eradicating poverty, ensuring equitable education, providing clean water, addressing climate change, and fostering sustainable economic growth by 2030 (United Nations, 2015; Sachs et al., 2019). The SDGs emphasize the need to balance economic development, environmental integrity, and social justice through evidence-based policy planning, cross-sectoral collaboration, and strategic

investment (Bebbington & Unerman, 2018). To operationalize sustainability within organizations, Environmental, Social, and Governance (ESG) indicators have emerged as critical tools. ESG metrics are now widely used to assess sustainability performance and align corporate activities with broader SDG targets (Eccles et al., 2012; Friede et al., 2015). These indicators provide measurable insights into how firms manage environmental risks, social impacts, and governance accountability, facilitating transparency and enabling performance benchmarking across industries. Achieving the SDGs requires collective action from multiple stakeholders, including governments, private enterprises, non-governmental organizations (NGOs), and civil society (Kolk, 2016). As part of this paradigm, integrating ESG principles into corporate strategy enables businesses to align with global sustainability targets while enhancing resilience, competitiveness, and long-term value creation.

**Sustainability Through the Lens of Environmental, Social, and Governance (ESG) Frameworks**

The ESG framework serves as a multidimensional structure for evaluating sustainability and ethical business practices. It provides a comprehensive mechanism to assess how organizations address critical environmental challenges, engage with societal issues, and maintain effective and transparent governance systems (Schaltegger & Wagner, 2017). The environmental component focuses on minimizing ecological impact and enhancing resource efficiency. This is particularly relevant for the steeling industries, which are high emission and resource intensive. Key strategies include reducing greenhouse gas emissions, improving energy efficiency, managing waste, and protecting biodiversity (Epstein & Roy, 2001; Saxena et al., 2022). The integration of environmentally responsible practices can lead to improved operational efficiency, cost savings, and compliance with increasingly stringent environmental regulations. The social dimension centers on the human aspects of business, such as employee welfare, labor rights, diversity and inclusion, community impact, and product responsibility. Organizations that invest in equitable labor practices, inclusive work environments, and active community engagement are more likely to gain stakeholder trust and loyalty (Ingram et al., 2019; Porter & Kramer, 2019). These practices also contribute to broader societal development goals outlined in the SDGs, reinforcing the role of the private sector in advancing social sustainability. Governance encompasses the internal structures, ethical standards, and oversight mechanisms that control corporate behavior. This includes anti-corruption measures, board accountability, financial transparency, and stakeholder engagement (Aras & Crowther, 2008). Strong governance systems reduce operational risks and enhance investor confidence, particularly in industries subject to regulatory and reputational scrutiny, such as the steel sector (Saxena et al., 2022).

Integrating ESG principles into business operations enables companies to better align with the SDGs while enhancing organizational resilience and long-term sustainability. The mapping of ESG activities to specific SDG targets facilitates strategic planning and investment decisions that prioritize impact and inclusiveness. For industrial sectors like steel, which face complex sustainability challenges, an ESG-based framework offers a structured pathway for improving performance across environmental, social, and governance dimensions (WCED, 1987; United Nations, 2015). Therefore, the adoption of ESG frameworks marks a fundamental evolution in corporate sustainability management. As firms navigate increasing pressures from regulators, investors, and society, ESG integration offers both a moral and strategic imperative. For heavy industries such as steel manufacturing, developing robust ESG-based measurement models is essential for aligning with international sustainability standards and achieving competitive advantage in a rapidly changing global economy.

In this study, the ESG framework proposed by Saxena et al., 2022, includes a detailed breakdown into three primary categories—Environmental, Social, and Governance. Each category encompasses several subtopics that cover critical areas of concern and interest for comprehensive sustainability assessments. Each category can be expanded to explain the specific topics covered as follows:

The environmental dimension of ESG focuses on how organizations manage their interactions with the natural environment and develop strategies to minimize adverse ecological impacts. One key area is climate change, which involves reducing greenhouse gas emissions, managing carbon footprints, and shifting toward renewable energy sources. Closely related is the concern with pollution and waste, where organizations implement waste reduction programs, efficient recycling systems, and controls for hazardous emissions. Another essential focus is resources and land use, which emphasizes sustainable consumption of natural inputs such as water, minerals, and forest products, along with responsible land-use planning and conservation. Furthermore, the ecological footprint concept encourages companies to evaluate and reduce their overall environmental impact throughout operations and the supply chain. Finally, biodiversity protection forms a vital part of environmental responsibility, requiring businesses to preserve ecosystems and species through conscientious planning and mitigation strategies.

The social dimension of ESG emphasizes the human and community impacts of business activities, both within and beyond organizational boundaries. Central to this dimension is health and safety, which focuses on safeguarding employee well-being through robust occupational health systems and emergency preparedness. Equally important is product and consumer responsibility, where firms are expected to uphold high standards in product safety, quality assurance, and ethical treatment of consumer rights throughout the product lifecycle. Businesses are also evaluated by their community impact, which includes contributions to local economic development, social infrastructure, and meaningful engagement with local stakeholders. Promoting diversity and inclusion is another critical aspect, requiring companies to enforce equal opportunity policies, prevent discrimination, and cultivate an inclusive organizational culture. Finally, upholding labor standards and human rights ensures compliance with international labor conventions, including the prohibition of child and forced labor and the promotion of fair working conditions across operations and supply chains.

The governance dimension of ESG pertains to the internal structures, leadership practices, and accountability mechanisms that guide corporate behavior and stakeholder interactions. A fundamental element is risk management, where organizations establish processes to identify, assess, and mitigate risks across financial, operational, and reputational domains. In parallel, anti-corruption and bribery measures are crucial to ensuring transparent operations, ethical transactions, and compliance with anti-bribery legislation. The commitment to business ethics is reflected in the adoption of codes of conduct and corporate values that promote integrity, fairness, and ethical decision-making at all levels. Moreover, tax transparency involves clear and honest reporting of tax practices, ensuring that companies comply with fiscal obligations in all jurisdictions of operation. Finally, leadership and corporate governance encompasses the responsibilities of boards and executives in promoting ethical leadership, board diversity, and responsive stakeholder engagement which are fundamental to achieving long-term sustainability and corporate legitimacy.

This structured approach to studying ESG components ensures a holistic assessment of an organization's practices and their alignment with sustainable development goals. It provides a

comprehensive blueprint for analyzing how these practices influence and contribute to long-term sustainability and ethical governance. This can be shown as shown in Figure 1 as follows.

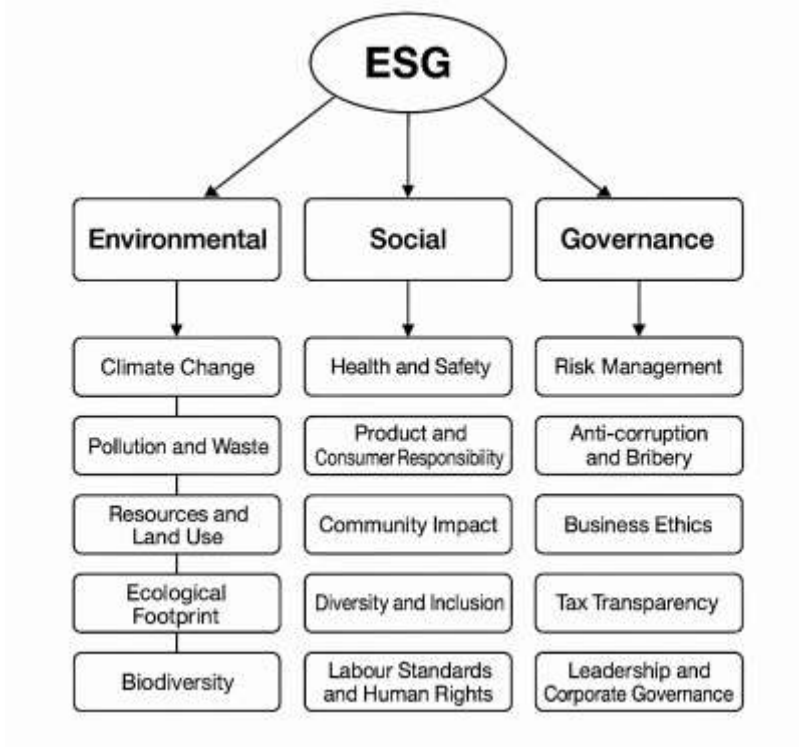


Figure 1: Conceptual Framework of ESG-Based Sustainability Measurement Model

## Research Methodology

This study employed quantitative research design using survey-based data collection to examine the multidimensional structure of ESG-related sustainability performance in the steel industry. A structured questionnaire was developed based on the ESG framework proposed by Saxena et al. (2022), comprising 45 items across 15 first-order constructs grouped under three second-order dimensions: Environmental, Social, and Governance. All items were measured using a five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). Data were collected from steel industry professionals in Thailand's Eastern Economic Corridor (EEC), using purposive sampling to ensure that respondents held relevant managerial or sustainability-related roles. A minimum sample size of 300 respondents was targeted, in line with SEM recommendations for complex hierarchical models (Hair et al., 2019). The data was analyzed using AMOS version 28, following a two-step procedure. First, Confirmatory Factor Analysis (CFA) was conducted to assess the validity and reliability of the first-order constructs, examining factor loadings, composite reliability (CR), and average variance extracted (AVE). Second, a Second-Order CFA was performed to validate the hierarchical structure of the ESG model, with each ESG dimension modeled as a second-order latent variable. Model fit was evaluated using standard indices, including $\chi^2$/df, CFI, TLI, RMSEA, and SRMR, in accordance with guidelines by Hair et al. (2019) and Kline (2016).

## Results

The overall model fit was assessed using multiple indices, each of which fell within the recommended thresholds, indicating a satisfactory fit of the proposed ESG-based measurement model. The model fit was evaluated using multiple goodness-of-fit indices, all of which indicated that the proposed measurement model demonstrated an acceptable to excellent fit. The Chi-square to degrees of freedom ratio ($\chi^2$/df) was 2.978, which falls below the commonly accepted threshold of 3.0, indicating an acceptable fit (Kline, 2016). The Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) were reported at 0.980 and 0.970, respectively—both exceeding the recommended benchmark of 0.95, thus signifying an excellent model fit (Hair et al., 2019). The Root Mean Square Error of Approximation (RMSEA) was 0.070, which falls within the acceptable range (≤ 0.08), though it slightly exceeds the optimal "good fit" threshold of 0.05 (Browne & Cudeck, 1993). Additionally, the Standardized Root Mean Square Residual (SRMR) was 0.069, which meets the acceptable criterion of being less than or equal to 0.08 (Hu & Bentler, 1999). Collectively, these indicators confirm that the measurement model is statistically sound and adequately fits the observed data.Taken together, these indicators confirm that the model demonstrates strong goodness-of-fit and supports the validity of the hypothesized second-order structure of the ESG measurement framework.

| **Fit Index** | **Recommended Threshold** | **Observed Value** | **Model Fit Evaluation** |
|---|---|---|---|
| **Chi-square / df ($\chi^2$/df)** | ≤ 3.00 | *2.978* | Acceptable Fit |
| **Comparative Fit Index (CFI)** | ≥ 0.90 (preferably ≥ 0.95) | *0.980* | Excellent Fit |
| **Tucker-Lewis Index (TLI)** | ≥ 0.90 | *0.970* | Excellent Fit |
| **Root Mean Square Error of Approximation (RMSEA)** | ≤ 0.08 (≤ 0.05 = good) | *0.070* | Excellent Fit |
| **Standardized Root Mean Square Residual (SRMR)** | ≤ 0.08 | 0.069 | Acceptable Fit |

Table1: Model Fit Indices of the ESG-Based Sustainability Measurement Model

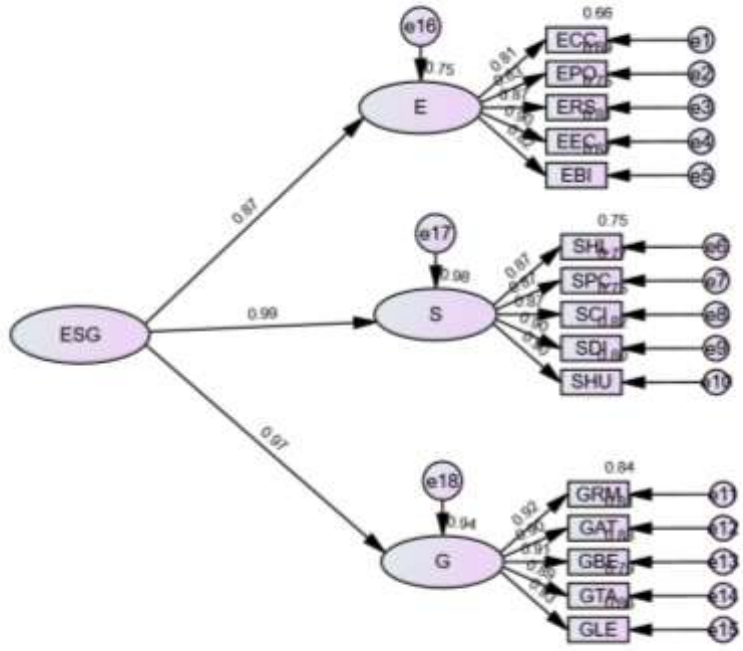


Figure 2: Measurement Model

| **Path** | **Std. Estimate** | **R²** | **S.E.** | **C.R.** | **P** | **AVE** |
|---|---|---|---|---|---|---|
| **Second-Order CFA** | | | | | | |
| E ← ESG | 0.888 | 0.789 | - | - | - | 0.732 |
| G ← ESG | 0.974 | 0.949 | 0.056 | 19.436 | *** | |
| S ← ESG | 0.999 | 0.998 | 0.056 | 18.221 | *** | |
| **First-Order CFA** | | | | | | |
| ECC ← E | 0.822 | 0.676 | - | - | - | 0.772 |
| EPO ← E | 0.839 | 0.703 | 0.048 | 20.125 | *** | |
| ERS ← E | 0.865 | 0.748 | 0.043 | 21.077 | *** | |
| EEC ← E | 0.888 | 0.789 | 0.048 | 22.184 | *** | |
| EBI ← E | 0.805 | 0.648 | 0.051 | 18.716 | *** | |
| SHL ← S | 0.861 | 0.742 | - | - | - | 0.821 |
| SPC ← S | 0.875 | 0.765 | 0.036 | 27.314 | *** | |
| SCI ← S | 0.870 | 0.757 | 0.045 | 23.649 | *** | |
| SDI ← S | 0.882 | 0.777 | 0.045 | 24.367 | *** | |
| SHU ← S | 0.874 | 0.763 | 0.047 | 23.959 | *** | |
| GRM ← G | 0.901 | 0.813 | - | - | - | 0.859 |
| GAT ← G | 0.874 | 0.763 | 0.040 | 26.613 | *** | |
| GBE ← G | 0.891 | 0.793 | 0.030 | 31.447 | *** | |

| | | | | | | |
|---|---|---|---|---|---|---|
| GTA ← G | 0.890 | 0.791 | 0.025 | 27.738 | *** | |
| GLE ← G | 0.935 | 0.874 | 0.033 | 31.565 | *** | |

Table 2: Results of Second-Order CFA – Regression Weights and Standardized Estimates

**Measurement Model Results**

The results from the second-order confirmatory factor analysis (CFA) support the structural validity of the ESG-based sustainability performance model in the steel industry context. The three second-order constructs—Environmental (E), Social (S), and Governance (G)—were found to significantly and positively contribute to the overarching construct of Sustainability Performance. All path coefficients were statistically significant at the 0.001 level ($p < 0.001$), indicating strong convergent validity among the constructs.

Specifically, the standardized regression weights from ESG to its second-order dimensions were: Social ($\beta = 0.999$), Governance ($\beta = 0.974$), and Environmental ($\beta = 0.888$). These results suggest that the social aspect of sustainability is perceived as the most influential component among steel industry stakeholders in Thailand, followed closely by governance and environmental factors. This finding aligns with prior studies emphasizing the critical role of social responsibility and stakeholder engagement in emerging market industries (Saxena et al., 2022; Zhou & Cui, 2022).

The Average Variance Extracted (AVE) for each second-order dimension exceeded the threshold of 0.50, confirming convergent validity (Hair et al., 2019). The AVE values for Environmental, Social, and Governance constructs were 0.732, 0.821, and 0.859, respectively.

At the first-order level, all sub-dimensions within each ESG domain exhibited high standardized factor loadings ($\beta > 0.80$), confirming the robustness of the measurement model. Notably, Leadership & Corporate Governance (GLE, $\beta = 0.935$, $R^2 = 0.874$) and Community Impact (SCI, $\beta = 0.870$, $R^2 = 0.757$) emerged as particularly strong indicators of governance and social performance, respectively. These findings reflect the increasing importance of executive accountability, board diversity, and community engagement in shaping sustainability perceptions in heavy industries.

The Environmental dimension also showed strong performance, with Ecological Footprint (EEC, $\beta = 0.888$, $R^2 = 0.789$) and Emissions & Pollution Control (ERS, $\beta = 0.865$, $R^2 = 0.748$) contributing most significantly. This supports prior observations by the World Steel Association (2021) that ecological impact and emissions management are critical concerns in the steel production process.

## Discussion and Implications

The validated measurement model underscores the multidimensional nature of sustainability and highlights the applicability of second-order CFA in assessing complex constructs such as ESG. The dominant role of the social dimension suggests that issues such as labor standards, health and safety, and community development remain top priorities in the steel industry, particularly in the EEC region of Thailand. This finding supports recent research advocating for greater stakeholder engagement and socially responsible operations in industrial sectors (Zhou & Cui, 2022). These results are also consistent with the study by Wattanakomol and Silpcharu (2022), who applied second-order confirmatory factor analysis to identify key management guidelines for sustainable success in Thailand's auto parts manufacturing industry. Their validated model, comprising dimensions such as servitization, organizational development, labor skill

enhancement, and technological advancement, illustrates that second-order CFA is a robust and adaptable method for modeling multidimensional constructs in industrial contexts. Although the content dimensions differ, both studies affirm the value of hierarchical models in capturing the strategic priorities that drive long-term sustainability in sector-specific applications.

The governance dimension, with strong loadings on leadership, ethics, and anti-corruption practices, reflects growing corporate accountability pressures, aligning with Velte (2022), who emphasized the role of governance in ESG disclosure quality. The environmental indicators further validate the operational importance of emission control, resource efficiency, and ecological impact management as outlined by the World Steel Association (2021). Practically, this model provides a validated tool for assessing sustainability performance in the steel sector, useful for internal audits, benchmarking, and ESG reporting. Theoretically, it extends the ESG literature by demonstrating the structural interrelationship among ESG components in a high-impact industrial context and affirms the value of second-order CFA as a methodological approach for developing sustainability measurement frameworks across diverse industrial sectors (Wattanakomol & Silpcharu, 2022).

This study contributes to the sustainability measurement literature by developing and validating a comprehensive, hierarchical ESG model tailored to the steel industry. It reinforces the use of second-order CFA as an appropriate method for modeling multidimensional constructs and complements existing ESG frameworks by offering empirical evidence from an emerging market context. Furthermore, the findings provide a basis for policy development and strategic decision-making in ESG management for resource-intensive industries.

### Research Ethics Approval

This study was reviewed and approved by the Human Research Ethics Committee of King Mongkut's Institute of Technology Ladkrabang, ensuring that the research complied with ethical standards for research involving human participants. All respondents were informed of the purpose of the study, assured of the confidentiality of their responses, and provided informed consent prior to participation. The study adhered to the principles outlined in the Declaration of Helsinki and followed institutional guidelines for the ethical conduct of research.

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