The Influence of Safety Observation on the 9 Building Blocks of Safety Model Canvas for a Dredging Company

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Abstract— **The dredging industry's dynamic and high-risk operational environment makes its safety culture a critical factor in preventing occupational accidents. However, the complex interplay between different dimensions of safety culture in such a unique, project-based context is not yet fully understood. This research aims to develop and empirically test a structural model that explains the causal relationships among the nine core dimensions of the Safety Model Canvas and evaluates the influence of Safety Observation program within this framework. This study employed a quantitative approach using Partial Least Square Structural Equation Modeling (SEM-PLS). Data were collected from a major Indonesian dredging company through 50-item questionnaires administered to 95 employees and an analysis of 595 formal Safety Observation reports. A model with 12 hypothesized paths was tested to validate the theoretical framework. The analysis confirmed the model's validity, with 8 of the 12 hypotheses being statistically significant. The findings reveal that the Safety Observation program significantly enhances both Engagement & Involvement and Information & Communication. A robust operational pathway was identified where proactive leadership fosters worker engagement, which in turn builds responsibility. However, the model also uncovered a critical systemic weakness in the organizational learning process, indicating a failure to effectively translate safety information into enhanced worker competence. This study contributes a validated causal model of safety culture, offering significant theoretical and practical insights for safety management in project-based maritime industries.**

Keywords— Dredging, Safety Culture, Safety Model Canvas, Safety Observation, SEM-PLS.

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I. INTRODUCTION

Indonesia, as a prominent maritime nation with a vast archipelago, relies heavily on its maritime sector for economic growth. This dependency necessitates robust infrastructure, particularly ports, to support trade and transportation. A primary challenge in maintaining port functionality is sedimentation, which reduces operational depth and hampers vessel navigation. Dredging is the primary solution to this issue, essential for both the construction and maintenance of harbours and shipping lanes. However, the dredging industry is inherently complex and fraught with significant occupational hazards.

The operational environment of dredging projects involves heavy machinery, dynamic working platforms on vessels, and unpredictable sea conditions, leading to a high risk of accidents. Common incidents include falls overboard, slips, trips, and contact with heavy equipment, which can result in serious injuries or fatalities [1]. The high rate of work-related accidents not only poses a threat to worker well-being but also leads to substantial economic and operational losses for companies. Although many firms have implemented safety management programs, accidents persist, highlighting the need for a deeper evaluation of safety effectiveness. This calls for an assessment of the underlying safety culture.

Safety culture is defined as the shared values, attitudes, perceptions, competencies, and patterns of behaviour that determine an organization's commitment to and proficiency in safety management [2][3]. Evaluating safety culture maturity can help identify areas for improvement and assess the effectiveness of existing safety programs [4]. Two powerful tools for this purpose are the Safety Model Canvas (SMC) and Safety Observation Cards (SOC). Safety Model Canvas is a visual framework used to design, analyse, and communicate various safety aspects, comprising nine building blocks that map the mechanisms of a safety system [5][6][7]. Meanwhile, Safety Observation Cards are a practical tool used by workers to report safe and unsafe behaviours and conditions, thereby promoting active engagement in safety monitoring.

The conceptual foundation of this study is the Safety Model Canvas, a framework that organizes safety culture into nine critical dimensions [8]. Foundational elements include Leadership, which is essential for steering organizational safety priorities, and Commitment from all levels of the organization. A key process variable is Organizational Learning, which refers to the organization's ability to learn from past incidents and near-misses to inform future decisions and prevent recurrences. This learning process is theorized to directly impact worker Competence, which encompasses not only formal training but also the practical ability to assess risks and perform tasks safely. These core processes are enhanced by worker Engagement & Involvement and a clear sense of Responsibility. The

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entire system is facilitated by effective Information & Communication channels, which act as the catalyst for action. This study models the interplay between these theoretical constructs to understand their collective impact on the ultimate goal: a state of Risk Controlled.

Previous research has explored the use of SMC and SOC independently in various industries like aviation and manufacturing. Studies have also utilized Structural Equation Modelling (SEM) to analyse relationships between safety culture variables. The dredging sector presents distinct challenges due to its dynamic, project-based operations across multiple separated vessel units. While previous studies have focused on assessing the maturity level of safety culture, less is known about the complex causal interrelationships between its core dimensions, particularly in dynamic and high-risk industries like dredging. Understanding these pathways is critical for designing effective and targeted interventions. Therefore, this study shifts the focus from mere assessment to causal modelling. It aims to develop and empirically test a comprehensive structural model based on the Safety Model Canvas framework, integrated with a practical Safety Observation program. Specifically, this study analyses the influence of Safety Observation on the relationships between the nine SMC building blocks using SEM-PLS. By analysing the direct and indirect effects among key variables such as leadership, organizational learning, and competence, this research seeks to provide a clearer understanding of the mechanisms that drive safety culture and to validate a model that can be used to guide strategic safety improvements in the dredging sector.

II. METHOD

This study employed a quantitative research approach to develop and test a structural model for evaluating safety culture maturity. The methodology involved model conceptualization, data collection from a dredging company, and statistical analysis using SEM-PLS.

A. *Conceptual Model and Hypotheses*

The research framework is built upon the Safety Model Canvas (SMC), which consists of nine interconnected building blocks categorized into five stages: Initial Awareness (Risk Perceived), Primary Key (Organizational Learning, Commitment, Leadership), Enhancement (Competence, Responsibility, Engagement & Involvement), Catalyst (Information & Communication), and Ultimate Goal (Risk Controlled) [9]. This study introduces Safety Observation as an intervention variable hypothesized to influence the Enhancement and Catalyst stages. Based on this framework and a review of relevant literature, twelve hypotheses (H1-H12) were formulated to test the causal relationships between the variables. The conceptual model illustrating these hypothesized relationships is shown in Figure 1. Grounded in this conceptual framework and a comprehensive review of prior research, a set of twelve hypotheses was developed to test the proposed causal relationships. The key hypotheses include testing the foundational pathways of the SMC and the specific influence of the intervention variable. Each hypothesis posits a specific link between the Safety Model Canvas variables and the Safety Observation intervention. The complete list of these formulated hypotheses, along with their respective theoretical underpinnings, is detailed in Table 1.

B. *Data Collection and Respondents*

Primary data was collected from a major dredging company operating in Indonesia. Two main instruments were used:

1) Questionnaire: A structured questionnaire was distributed to 95 employees, including both management and operational staff from various vessel units. The questionnaire consisted of 50 items designed to measure the 10 latent variables (9 SMC blocks and safety observation) using a 5-point Likert scale, ranging from 1 (Basic) to 5 (Resilient). Each item was carefully developed based on indicators validated in previous studies to ensure content validity.
2) Safety Observation: Observational data was collected from 595 internal Safety Observation Card reports submitted by workers between January 2024 and May 2025. These findings were categorized into five levels based on their nature: Unsafe Action (score 1), Unsafe Condition (2), Improvement Suggestion (3), Safe Condition (4), and Safe Action (5). This categorization allowed for the quantification of behavioural and conditional observations in the field.

The respondent pool was diverse in terms of age, job tenure, and position, providing a comprehensive overview of the company's safety culture from multiple perspectives.

C. *Data Analysis*

The collected data was analysed using a multi-step process. First, a safety culture maturity score was calculated to provide overall context, followed by the primary analysis using Structural Equation Modelling - Partial Least Square (SEM-PLS) to test the hypothesized model.

Safety Culture Maturity Score Calculation: An overall maturity score was calculated for the company and each of its units. This was achieved by first calculating the average scores from the questionnaire data and the categorized Safety Observation data separately. These two scores were then combined using a weighted average. The weights were determined by multiple linear regression, which indicated an equal contribution 50% from each perception (questionnaire) and observation. The final score was mapped to one of five maturity levels: Basic, Reactive, Planned, Proactive, or Resilient [10].

Structural Equation Modeling (SEM-PLS): The hypothesized model (Figure 1) was tested using SEM-PLS with SmartPLS 4 software. This method was chosen over Covariance-Based SEM (CB-SEM) due to its suitability for this research, which is focused on theory development and prediction within a complex model. SEM-PLS is advantageous as it does not require normally distributed data, is robust with smaller sample sizes, and can handle complex models with many indicators and constructs without issues of model identification. The analysis followed a two-stage procedure as recommended for SEM-PLS:

1) Measurement Model Evaluation: The first stage was to assess the reliability and validity of the measurement model. This ensures that the indicators used are consistently and accurately measuring their respective latent constructs. Three key criteria were evaluated:

- Convergent Validity: This was assessed by examining the outer loadings of the indicators. A loading factor (λ) greater than 0.5 is considered acceptable for establishing that an indicator is valid for its construct.
- Internal Consistency and Reliability: This was evaluated using Cronbach's Alpha (α) and Composite Reliability (ρc). Both values should be greater than 0.70 to indicate that the indicators for a given construct are reliably measuring the same underlying concept.
- Discriminant Validity: This was confirmed using the Fornell-Larcker criterion, which requires that the square root of the Average Variance Extracted (AVE) for a construct is greater than its correlation with any other

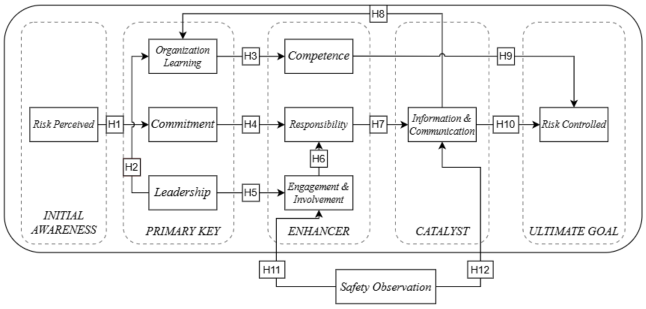

Figure 1. The Hypothesized Structural Model

TABLE 1.
HYPOTHESES PROPOSED

Hypothesis	Relationship	Reference
H1	Risk Perceived has a positive influence on Commitment	[15]
H2	Leadership has a positive influence on Organizational Learning	[16]
H3	Organizational Learning has a positive influence on Competence	[18][17][11]
H4	Commitment has a positive influence on Responsibility	[19][11]
H5	Leadership has a positive influence on Engagement & Involvement	[18][17][11]
H6	Engagement & Involvement has a positive influence on Responsibility	[18][17][11]
H7	Responsibility has a positive influence on Information & Communication	[21][17][11]
H8	Information & Communication has a positive influence on Organizational Learning	[21][17][11]
H9	Competence has a positive influence on Risk Controlled	[11]
H10	Information & Communication has a positive influence on Risk Controlled	[18][17][11]
H11	Safety Observation has a positive influence on Engagement & Involvement	[22][23][24][25]
H12	Safety Observation has a positive influence on Information & Communication	[22][23][24][25]

construct in the model [11]. This ensures that each construct is empirically distinct.

2) Structural Model Evaluation: After confirming the measurement model's robustness, the second stage was to evaluate the structural model to test the hypothesized relationships. This involved assessing key metrics included the coefficient of determination (R^2), effect size (f^2), and the significance of path coefficients (β) [12].
   - Coefficient of Determination (R^2): This measures the model's predictive power, with values of 0.67, 0.33, and 0.19 considered substantial, moderate, and weak, respectively [13].
   - Effect Size (f^2): This assesses the impact of a specific predictor construct on an endogenous construct, with values of 0.35, 0.15, and 0.02 considered large, medium, and small effects, respectively.
   - Path Coefficients (β): The significance of the hypothesized paths was determined using a bootstrapping procedure (5,000 resamples). A path was considered statistically significant if its t-statistic was greater than 1.96 and its p-value was less than 0.05 [14].

III. Results and Discussion

This section presents the results of the data analysis, beginning with the respondent demographics, followed by a detailed evaluation of the measurement and structural models, and concluding with an in-depth discussion of the hypothesis testing.

A. Respondent Characteristics

The 95 respondents formed a representative sample of the company's workforce. Demographically, 52.6% were under 30 years old, while 47.4% were 30 or older. In terms of experience, a slight majority (54.7%) had been with the company for five years or more. The sample was heavily weighted towards operational roles, with 70.5% of respondents being directly involved in fieldwork, while the remaining 29.5% held supervisory positions. This composition ensures that the findings are well-grounded in the practical realities of dredging operations.

B. Measurement Model Assessment

The first step in the SEM-PLS analysis was to validate the measurement model to ensure that the indicators reliably and validly measure their respective latent constructs. This was confirmed through assessments of reliability and validity.

1) Internal Consistency Reliability and Convergent Validity: The results confirmed the robustness of the measurement model. All ten constructs exhibited strong internal consistency, with both Cronbach's Alpha and Composite Reliability values well above the recommended 0.7 threshold, indicating that the indicators for each construct consistently measure the same underlying concept. Furthermore, all indicators demonstrated acceptable convergent validity, with outer loadings ranging from 0.439 to 0.872. While some indicators were below the ideal 0.7 level, none fell below the critical threshold of 0.4, making them acceptable for retention in the model. A summary of these reliability and validity results is presented in Table 2.
2) Discriminant Validity: Discriminant validity was successfully established through the Fornell-Larcker criterion and an analysis of cross-loadings. The analysis confirmed that each indicator loaded more strongly on its own intended construct than on any other construct. Additionally, the square root of the

Table 2.
Cronbach's Alpha and Composite Reliability

Variable	Cronbach's Alpha	Composite Reliability	Status
Commitment	0.759	0.836	Reliable
Competence	0.784	0.851	Reliable
Engagement & Involvement	0.765	0.837	Reliable
Information & Communication	0.748	0.826	Reliable
Leadership	0.773	0.842	Reliable
Organization Learning	0.767	0.840	Reliable
Responsibility	0.801	0.857	Reliable
Risk Controlled	0.778	0.843	Reliable
Risk Perceived	0.721	0.814	Reliable
Safety Observation Card	0.714	0.817	Reliable

Average Variance Extracted (AVE) for each construct was greater than its correlation with all other constructs in the model. This ensures that each construct is empirically distinct and measures a unique concept, confirming the overall validity of the measurement model. The detailed results for this analysis are presented in Table 3.

C. Structural Model Assessment

After confirming the measurement model's validity and reliability, the structural model was evaluated to assess its predictive power and the relationships between the constructs.

1) Coefficient of Determination (R^2): The R^2 value indicates the proportion of variance in the endogenous (dependent) variables that can be explained by the exogenous (predictor) variables. The results showed moderate predictive power for several key variables, including Risk Controlled (R^2 = 0.477), Information & Communication (R^2 = 0.473), and Engagement & Involvement (R^2 = 0.385). Other variables such as Organizational Learning, Commitment, and Responsibility showed weak predictive power, suggesting that other factors not included in the model also influence them.
2) Effect Size (f^2): The effect size (f^2) was analysed to determine the substantive impact of each predictor variable on the dependent variables. The analysis revealed a large effect of Competence on Risk Controlled (f^2 = 0.579), highlighting its critical importance. Moderate effects were found for several key relationships, including Risk Perceived on Commitment (f^2 = 0.337), Responsibility on Information & Communication (f^2 = 0.305), and Leadership on Engagement & Involvement (f^2 = 0.275). Other relationships demonstrated a small effect size. The overall assessment of the measurement and structural models indicates that the model is reliable, valid, and possesses adequate predictive relevance for the key relationships, providing a solid foundation for testing the individual hypotheses.

D. Hypothesis Testing and Discussion

The structural model was evaluated to test the twelve hypotheses. The results revealed a mix of supported and unsupported relationships, providing a nuanced view of the safety culture dynamics at the company. Eight of the twelve hypotheses were accepted. A detailed summary of the results for all twelve hypotheses is presented in Table 4 and Figure 2.

TABLE 3.
FORNELL-LARCKER CRITERION

Variable	C	CO	EI	IC	L	OL	R	RC	RP	SOC
C	0.712									
CO	0.100	0.731								
EI	0.154	0.370	0.715							
IC	0.101	0.067	0.149	0.700						
L	0.178	0.122	0.363	0.161	0.720					
OL	0.471	0.142	0.120	0.342	0.171	0.718				
R	0.142	0.255	0.306	0.383	0.144	0.239	0.740			
RC	0.080	0.458	0.327	0.115	0.142	0.146	0.140	0.724		
RP	0.347	0.437	0.574	0.237	0.328	0.233	0.312	0.330	0.684	
SOC	0.018	0.128	0.273	0.330	0.210	0.071	0.185	0.148	0.463	0.699

1) Hypothesis 1 (H1), Risk Perceived to Commitment: The analysis showed a significant positive relationship between Risk Perceived and Commitment (β = 0.347; t = 5.222; $p < 0.001$), supporting H1. This finding is consistent with literature that identifies the positive relationship between perceived risk and commitment to safety [15]. When workers in the dredging company consciously acknowledge the high risks of their operational activities, this awareness fosters a stronger personal and collective commitment to adhering to safety protocols.
2) Hypotheses 2 & 3 (H2, H3), The Organizational Learning Pathway: The model revealed a critical weakness in the organizational learning loop. The path from Leadership to Organizational Learning (H2) was not significant (β = 0.119; t = 0.729; $p > 0.05$). This result is not in accordance with the previous research which stated that leadership variables have a positive relationship with organizational learning [16]. However, the rejection of this hypothesis is in accordance with another research where leadership does not have a positive relationship with organizational learning [17][11]. Similarly, the path from Organizational Learning to Competence (H3) was also not significant (β = 0.142; t = 1.013; $p > 0.05$). This result is not in accordance with the research where the results of the study stated that organizational learning has a

positive or significant relationship with competence [18]. This sequential failure suggests a systemic issue. Unlike static industrial settings, the dynamic and project-based nature of dredging operations may impede the effective institutionalization of learning. Competence is likely perceived by vessel crews as being derived more from formal maritime certifications and direct operational experience rather than from company-wide learning programs. This indicates a failure to effectively translate communicated safety information and leadership directives into a collective knowledge base that systematically enhances worker competence.

3) Hypothesis 4 (H4), Commitment to Responsibility: The relationship between Commitment and Responsibility was found to be insignificant ($\beta = 0.097$; $t = 0.737$; $p > 0.05$), rejecting H4. This result is not in accordance with the research where the results of the study stated that commitment has a positive or significant relationship with responsibility [19]. However, this result whilst counterintuitive, it aligns with findings in other industries where safety management systems are still maturing [20]. It suggests that while management may demonstrate commitment through policies and resources, this does not automatically translate into a felt sense of personal responsibility among workers. The link appears to be indirect and requires other mediating factors, such as active engagement.
4) Hypotheses 5, 6, & 7, The Operational Pathway: The model confirmed a strong and logical operational pathway. Leadership has a significant positive influence on Engagement & Involvement (H5: $\beta = 0.320$; $t = 2.807$; $p < 0.01$). These results are in accordance with previous research where the results of these studies stated that leadership has a positive or significant relationship with engagement & involvement [18][17][11]. This active engagement, in turn, significantly fosters a sense of Responsibility among workers (H6: $\beta = 0.291$; $t = 3.029$; $p < 0.01$). These results are in accordance with previous research where the results of these studies stated that engagement & involvement have a positive or significant relationship with responsibility [18][17][11]. Finally, this heightened responsibility promotes better Information & Communication (H7: $\beta = 0.334$; $t = 3.225$; $p < 0.01$). These results are in accordance with previous research where the results of these studies stated that responsibility has a positive or significant relationship with information & communication [21][17][11]. This chain demonstrates that proactive leadership on vessels is key to unlocking a virtuous cycle of engagement and accountability.
5) Hypothesis 8 (H8), Information & Communication to Organizational Learning: A significant positive relationship was found between Information & Communication and Organizational Learning ($\beta = 0.323$; $t = 2.695$; $p < 0.01$). These results are in accordance with where the results of these studies stated that information & communication has a positive or significant relationship with organizational learning [21][17][11]. This supports the notion that effective communication channels are the primary feedstock for organizational learning. The organization can only learn from near-misses and incidents if there is a robust system for reporting and discussing them.
6) Hypotheses 9 & 10, Pathways to Risk Controlled: Competence was found to be a very strong and significant predictor of Risk Controlled (H9: $\beta = 0.452$; $t = 6.621$; $p < 0.001$). These results are in accordance with the previous research where the results of the study stated that competence has a positive or significant relationship with risk control, reinforced by arguments from the international standard ISO 45001:2018 [11]. This underscores the critical importance of worker skill, knowledge, and ability to manage risks effectively in the field. However, the direct path from Information & Communication to Risk Controlled (H10) was not significant ($\beta = 0.085$; $t = 0.767$; $p > 0.05$). This result is not in accordance with the previous research where the results of the study stated that information & communication has a positive or significant relationship with risk controlled [18][17][11]. This suggests that information alone is insufficient to control risk; it must first be translated into competence or other actions.

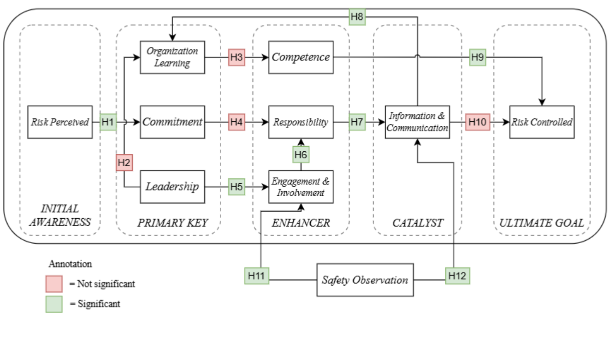

Figure 2. Results of the Structural Model Analysis

7) Hypotheses 11 & 12, The Influence of Safety Observation: The Safety Observation program proved to be a highly effective intervention. It had a significant positive influence on both Engagement & Involvement (H11: $\beta = 0.206$; $t = 2.126$; $p < 0.05$) and Information & Communication (H12: $\beta = 0.269$; $t = 2.393$; $p < 0.05$). These results are in accordance with previous research where the results of the research stated that there is a relationship between safety observation cards with information & communication and worker engagement & involvement in safety aspects [22][23][24][25]. This confirms that the program serves as a powerful catalyst, not only by structuring the flow of safety information but also by providing a formal mechanism that encourages and empowers workers to actively participate in safety management. This finding is consistent with studies highlighting the positive impact of such behavioral observation systems.

TABLE 4.
HYPOTHESES RESULTS

Hypothesis	Path	Path Coefficients (β)	t-statistics	p-values	Result
H1	Risk Perceived to Commitment	0.347	5.222	0.000	Significant, accepted
H2	Leadership to Organizational Learning	0.119	0.729	0.466	Not significant, rejected
H3	Organizational Learning to Competence	0.142	1.013	0.311	Not significant, rejected
H4	Commitment to Responsibility	0.097	0.737	0.461	Not significant, rejected
H5	Leadership to Engagement & Involvement	0.320	2.807	0.005	Significant, accepted
H6	Engagement & Involvement to Responsibility	0.291	3.029	0.002	Significant, accepted
H7	Responsibility to Information & Communication	0.334	3.225	0.001	Significant, accepted
H8	Information & Communication to Organizational Learning	0.323	2.695	0.007	Significant, accepted
H9	Competence to Risk Controlled	0.452	6.621	0.000	Significant, accepted
H10	Information & Communication to Risk Controlled	0.085	0.767	0.443	Not significant, rejected
H11	Safety Observation to Engagement & Involvement	0.206	2.126	0.034	Significant, accepted
H12	Safety Observation to Information & Communication	0.269	2.393	0.017	Significant, accepted

IV. CONCLUSION

This study successfully developed and validated a structural equation model that delineates the complex interrelationships of safety culture dimensions within the unique context of the dredging industry. The primary achievement of this research is the empirical confirmation of a model that maps the critical pathways influencing safety outcomes. Based on the objective of this paper, the conclusions are:

1) The developed structural model was successfully validated, explaining the causal relationships between the nine dimensions of the Safety Model Canvas and the influence of a Safety Observation program. The model demonstrated good fit and predictive relevance.
2) The model reveals that operational safety pathways driven by leadership that fosters engagement, which in turn builds responsibility and enhances communication are robust and function as theorized. Crucially, the Safety Observation program acts as a significant catalyst in this process.
3) A critical systemic failure was identified in the organizational learning loop, where the translation of leadership directives and communicated information into collective learning and tangible worker competence is significantly weak. This disconnect represents the most critical area for managerial intervention.

The primary contribution of this research is the provision of an empirically tested model that moves beyond simple maturity assessment to explain how safety culture functions in a dynamic, project-based maritime environment. The findings offer valuable theoretical insights and provide a clear, data-driven basis for practitioners to diagnose systemic weaknesses and prioritize interventions to build a more resilient safety culture.

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