

A Decade of Bridge Resource Management - An Analytical Review

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ABSTRACT

Bridge Resource Management (BRM) has become a fundamental framework for improving navigational safety in response to the increasing complexity of modern maritime operations. Despite significant advances in ship technology, accident investigations consistently identify human and organizational factors such as poor communication, inadequate situational awareness, ineffective leadership, and weak teamwork as primary contributors to maritime casualties. This study presents an analytical review of the development, application, and effectiveness of BRM over the past decade, since it full adapted in 2017 with particular emphasis on its role in mitigating human error and strengthening maritime safety culture.

The research examines the evolution of BRM from its origins in aviation Crew Resource Management (CRM) to its formal integration into the international regulatory framework through the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) and related International Maritime Organization (IMO) guidance. It analyzes current BRM training methods, regulatory requirements, and operational practices, drawing on academic studies, industry publications, and international standards. The findings indicate that while BRM has been widely institutionalized and contributes positively to safety awareness, its practical effectiveness is often limited by inconsistent training standards, individual-focused learning approaches, hierarchical barriers to communication, and inadequate assessment and feedback mechanisms.

The study concludes that BRM must evolve from a compliance-driven training requirement into a continuous, team-based operational practice embedded in daily bridge operations. Recommendations are proposed for maritime authorities, training academies, and shipping companies to enhance BRM effectiveness through scenario-based team training, improved assessment methods, constructive feedback systems, and stronger integration of human–automation interaction.

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1. Introduction.

Maritime transportation represents one of the most efficient and economically viable modes of global trade; however, the rapid growth in shipping activities, vessel size, and traffic density has significantly increased the complexity of navigational operations. Within this context, Bridge Resource Management (BRM) has emerged as a critical framework for enhancing navigational safety through the effective coordination and utilization of human, technical, and informational resources available

on the ship's bridge. BRM is defined as a systematic approach that integrates planning, communication, decision-making, and teamwork to ensure safe and efficient vessel operations throughout all stages of a voyage (Kodak & Dal, 2024).

Despite advancements in operational frameworks and maritime technologies, human factors remain the dominant cause of maritime accidents. Empirical evidence indicates that deficiencies in communication, situational awareness, leadership, and teamwork significantly contribute to navigational errors and operational failures. In this regard, BRM plays a vital role in minimizing human error by fostering effective communication, enhancing situational awareness, and supporting collaborative decision-making among bridge team members. Moreover, BRM extends beyond technical operations to address cognitive and

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behavioral aspects such as stress management, workload distribution, and risk perception, which are essential for safe maritime operations (Kodak & Dal, 2024).

The concept of BRM originates from Crew Resource Management (CRM) in the aviation industry, which was developed to reduce human error in flight operations. This concept was subsequently adapted to the maritime domain as a structured approach to improving teamwork and operational safety on board ships. The framework emphasizes the effective use of all available resources, including navigational equipment, communication systems, and human expertise, to detect and mitigate errors before they escalate into accidents (NI, 2014).

In recognition of its importance, international regulatory frameworks, particularly the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), have incorporated BRM as a mandatory component of Maritime Education and Training (MET). The STCW highlights the development of both technical and non-technical competencies, increasingly delivered through simulator-based training to enhance realism and operational preparedness (Zhang, 2017).

Nevertheless, several challenges remain in the implementation of BRM, including inconsistencies in training standards, limitations in assessment methodologies, and variations in application across MET institutions. In addition, the integration of emerging technologies into bridge operations introduces further complexities that require continuous adaptation. Therefore, this study aims to provide an analytical review of BRM over the past decade, focusing on its evolution, application, and impact on maritime safety, while identifying existing gaps and proposing future directions to enhance its effectiveness in modern maritime operations.

2. Concept and Evolution of BRM.

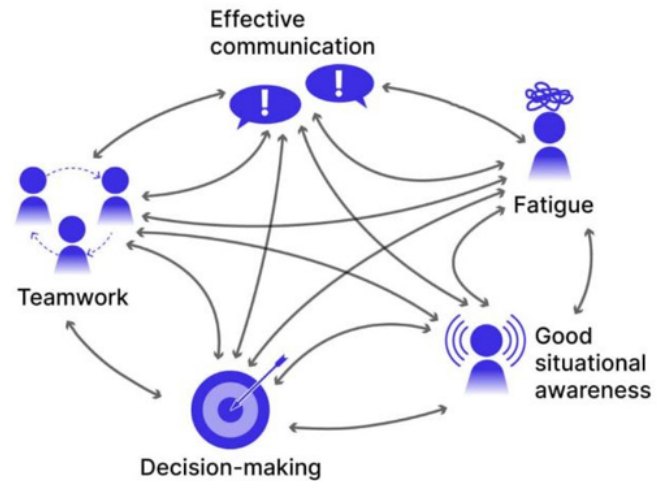
BRM is a maritime safety framework developed to improve navigational performance through the effective management of human, technical, and organizational resources on the ship's bridge. Introduced in the early 1990s and adapted from CRM, the framework addresses human-error-related challenges in communication, leadership, and decision-making. Its formal incorporation into the STCW Convention, becoming mandatory following the Manila 2010 Amendments, marked a significant advancement in strengthening global maritime safety standards (Jürgen, 2020).

Building on this regulatory foundation, BRM transformed traditional bridge management practices by shifting from rigid hierarchical control toward a collaborative, team-based approach. While the master retains overall authority, BRM emphasizes shared situational awareness, assertive communication, collective decision-making, and function-based role allocation. This transition reflects evidence that maritime accidents are more frequently associated with failures in teamwork and communication than with technical shortcomings alone (Sondell & Lyman, 2020).

In parallel with these structural changes, BRM has expanded to incorporate key principles from human factors research, with

particular emphasis on non-technical skills such as situational awareness, leadership, communication, decision-making, and the management of stress and fatigue (see Fig.1). Given that human error accounts for a substantial proportion of maritime accidents, BRM integrates structured approaches to human performance, including established error-management models such as the Swiss Cheese Model, and promotes a just culture in which errors are treated as systemic learning opportunities rather than individual failings (Jürgen, 2020).

Figure 1: Key components of BRM (Knudsen, 2025).



Source: Authors.

More recently, BRM has continued to evolve in response to increasing automation and technological complexity on modern ship bridges. While advanced navigational systems enhance operational capability, they also introduce challenges related to reduced vigilance, overreliance on automation, and potential degradation of manual skills. Although BRM training may primarily reinforce existing positive attitudes toward non-technical skills, it remains essential for maintaining safety awareness, standardizing best practices, and supporting continuous professional development. Consequently, BRM is widely recognized as a cornerstone of contemporary maritime safety culture in increasingly technology-driven bridge environments (Jürgen, 2020).

3. Human Factors and Maritime Safety.

Human factors have long been recognized as one of the most significant contributors to maritime accidents and incidents, despite continuous improvements in navigational technology and vessel design. Research consistently demonstrates that the majority of maritime casualties are caused not by technical failures but by human error associated with non-technical skills not limited to poor judgment, ineffective communication, inadequate situational awareness, and weak leadership. In the maritime context, human factors encompass the physical, cognitive, and organizational influences that affect the performance

of seafarers in safety-critical environments. Consequently, understanding and managing these factors has become a central objective of modern maritime safety management and BRM training programs (Zhang, 2017).

A key dimension of human factors in maritime safety is the interaction between technical skills (hard skills) and non-technical skills (soft skills). Hard skills refer to the operational competencies required to navigate and control the vessel, including the use of navigational instruments, adherence to procedures, and compliance with international regulations. In contrast, soft skills include communication, teamwork, leadership, decision-making, and situational awareness. Studies indicate that even highly competent officers may fail to maintain safe operations if these non-technical skills are lacking. Therefore, BRM emphasizes the integration of hard and soft skills in training and assessment to improve overall bridge team performance and reduce the likelihood of human-related incidents (Zhang, 2017).

Furthermore, situational awareness and workload management are critical human factors affecting navigational safety. Situational awareness refers to the ability of bridge team members to perceive, comprehend, and anticipate changes in the vessel's internal and external environment. Loss of situational awareness can lead to delayed responses, poor decision-making, and increased collision or grounding risks. Similarly, excessive workload, fatigue, and stress can impair cognitive performance and reduce operational effectiveness. For this reason, modern maritime safety frameworks and the STCW Convention emphasize human factors training through simulator-based exercises and scenario-based assessments, enabling seafarers to develop both technical competence and the non-technical skills necessary for safe and effective ship operations (Zhang, 2017).

4. Regulatory Framework and International Standards.

The regulatory framework governing BRM is established under the STCW 1978, as amended, and its associated STCW Code. The Convention provides the legal foundation for uniform international standards, while the STCW Code elaborates on the detailed technical and operational requirements. Part A of the Code contains mandatory minimum standards, whereas Part B provides recommended guidance to support uniform implementation by Administrations and training institutions (IMO, 2017).

BRM is embedded within the mandatory competence requirements for deck officers at both operational and management levels, principally under Regulations II/1, II/2, II/3, II/4, and II/5 of the STCW Convention and the corresponding competence tables in sections A-II/1 and A-II/2 of the STCW Code. These provisions require officers to demonstrate effective use of human and technical resources, including communication, leadership, task allocation, situational awareness, workload management, and decision-making during navigational operations. Competence in BRM must be demonstrated through approved training, in-service experience, simulator-based assessment, or a combination thereof (IMO, 2017).

The 2010 Manila Amendments significantly strengthened the international standards related to BRM by updating competence requirements to reflect advances in technology and lessons learned from casualty investigations. These amendments emphasize the human element in maritime safety and explicitly link effective bridge organization and teamwork with safe watchkeeping practices. In addition, Regulation VIII/2 of the STCW Convention reinforces BRM principles by requiring Administrations and masters to ensure that watchkeeping arrangements support safe navigation at all times, taking into account fatigue, fitness for duty, and effective communication among bridge team members (IMO, 2017).

International enforcement and quality assurance of BRM standards are supported through mechanisms such as port State control, mutual recognition of certificates between Parties, and the International Maritime Organization (IMO) Member State Audit Scheme. Administrations are required to maintain quality standards systems for training and assessment, including periodic independent evaluations, to ensure that BRM competencies are effectively delivered and maintained. Collectively, this framework establishes BRM as a globally harmonized and enforceable standard, integral to navigational safety and the prevention of human-error-related maritime accidents (IMO, 2017).

5. Training Methods and Implementation of BRM.

The IMO Model Course 1.22, 2023 Edition, establishes the formal training methodology for BRM in accordance with the STCW Convention. It defines BRM training as a structured combination of workshops, guided discussions, and simulator-based exercises focused on developing both technical and non-technical competencies required for maintaining a safe navigational watch. The model course places particular emphasis on learner involvement, requiring trainees to demonstrate knowledge, understanding, and proficiency through scenario-based tasks rather than passive lectures. Simulator exercises are mandatory where facilities are available and are used to assess behaviors such as communication, leadership, workload management, and situational awareness using briefing, execution, and debriefing cycles. This approach reflects the IMO's objective of standardizing BRM training globally while allowing administrations and training providers to adapt delivery methods to trainee experience and operational context (IMO, 2023).

From an operational implementation perspective, The Nautical Institute's *The Navigator* (October 2014) describes how BRM principles must be embedded into daily bridge operations rather than treated solely as a training requirement. The publication highlights that effective BRM implementation begins with voyage planning and continues throughout watchkeeping, pilotage, and end-of-voyage debriefing. Particular importance is placed on bridge team organization, clear definition of roles, and continuous monitoring of the vessel's progress to maintain situational awareness. The Master is identified as a central figure in reinforcing BRM onboard by encouraging open communication, responsible challenge and response, and proper use of available human and technical resources. According to the Nautical Institute, sustained BRM effectiveness de-

depends on consistent practice, reflection, and improvement through audits, near-miss discussions, and refresher training (NI, 2014).

An evidence-based analysis of BRM training effectiveness is presented in O'Connor's 2011 academic study. This research evaluates BRM training by examining changes in knowledge and attitudes related to human factors and safety-critical behavior. The study indicates that BRM training outcomes vary significantly depending on how well course content reflects the actual operational environment and whether training is supported by a systematic needs assessment. It emphasizes that without alignment between training objectives, organizational practices, and real-world risks, BRM training may fail to produce meaningful behavioral change. The findings underline the importance of continuous evaluation, feedback mechanisms, and data-driven course development to ensure that BRM training contributes effectively to long-term safety performance rather than remaining a procedural compliance exercise (Kodak & Dal, 2025).

6. Analysis of BRM Applications Over the Last Decade.

Over the last decade, since the full adapted in 2017 BRM has remained a central mechanism for addressing human factor-related risks in maritime operations, particularly given the enduring evidence that human and organizational errors are responsible for the majority of maritime accidents. Research has consistently shown that more than 80 percent of accidents at sea can be traced to deficiencies in communication, decision making, leadership, and situational awareness rather than to technical failures alone. As a result, BRM has been widely institutionalized within MET frameworks. However, despite its widespread adoption, BRM application over the past decade has often lagged behind aviation in terms of standardization, systematic assessment, and integration across the full socio-technical system on board ships (Griffioen et al., 2021).

A defining feature of the BRM application during this period has been the growing recognition of leadership as a determining factor in its effectiveness. Empirical studies indicate that transformational leadership styles, characterized by intellectual stimulation and open communication, are strongly associated with a positive safety climate and more effective crew coordination. Shipmasters who actively encourage feedback, dialogue, and shared responsibility enable BRM principles to function in practice rather than remain theoretical. In contrast, *laissez-faire* leadership has been linked to weaker safety cultures and diminished compliance with BRM practices. This evidence suggests that BRM effectiveness is not solely a function of training content, but is deeply dependent on how leadership styles shape everyday operational behavior and decision-making on board (Kılıçlı et al., 2025).

Evaluation studies conducted over the last decade also highlight persistent challenges in measuring the effectiveness of BRM training. Research examining pre and post-course attitudes toward non-technical skills often reports no statistically significant changes following BRM courses, despite high levels of perceived learning among participants. This apparent contradiction is largely explained by high baseline scores, as many

officers already acknowledge the importance of these skills before training. Consequently, BRM in practice has tended to reinforce existing attitudes rather than fundamentally transform them. Methodological limitations, including reliance on self-reported Likert scale surveys, long delays between training and follow-up assessments, and lack of qualitative validation, further limit the ability of studies to capture subtle behavioral changes that may nevertheless be operationally significant (Sondell & Lyman, 2020).

In more recent years, BRM applications have begun to evolve through the incorporation of resilience engineering and competence-based training models. Rather than focusing exclusively on error prevention, contemporary BRM frameworks emphasize adaptability, team resilience, and the ability of crews to anticipate, monitor, respond, and learn under varying operational conditions. Training designs increasingly rely on simulator-based scenarios of escalating complexity, repeated exposure over several academic years, and assessment based on observable behavioral markers. This shift reflects a broader transition in BRM application over the past decade, from a one-time compliance-oriented intervention toward a continuous learning process aimed at strengthening long-term maritime safety performance and organizational resilience (Griffioen et al., 2021).

7. Challenges and Limitations in BRM Implementation.

One of the most persistent challenges in the implementation of BRM over the last decade is the insufficient contextual adaptation of training programs to the maritime domain. Much of maritime BRM has historically been transferred almost directly from aviation-based CRM models, with limited adjustment to ship-specific operational realities, organizational structures, and cultural conditions. This has resulted in training that emphasizes generic non-technical skills without fully accounting for long voyage durations, stable crew compositions, multicultural environments, and strongly hierarchical command structures that characterize maritime operations. As a result, BRM principles learned in classroom settings may not easily translate into changed work practices on board ships (Wahl & Kongsvik, 2018).

A further limitation relates to the dominance of individual-oriented learning and assessment approaches in BRM training. The literature consistently indicates that BRM courses tend to focus on individual officers attending training in isolation from their regular crews, with limited opportunity for collective reflection or team-based learning. This contradicts the operational reality in which BRM effectiveness depends on coordinated team behavior rather than individual competence alone. The absence of training entire bridge teams together restricts the development of shared mental models, mutual trust, and collective situational awareness, which are essential for effective resource management in dynamic maritime environments (Wahl & Kongsvik, 2018).

Organizational hierarchy and authority gradients represent another major barrier to effective BRM implementation. Several studies highlight that strict hierarchical structures on board

ships can inhibit open communication, assertiveness, and challenge - and - response behaviors that BRM explicitly aims to promote. Junior officers and ratings may be reluctant to question senior officers' decisions due to fear of blame, punitive responses, or negative career consequences. This undermines core BRM principles such as shared decision-making and effective communication, particularly during high-risk or emergencies where rapid information exchange is critical (Wahl & Kongsvik, 2018).

Finally, the assessment and evaluation of BRM outcomes remain a significant limitation. Evidence from recent studies shows that while BRM training often increases awareness of non-technical skills, measurable changes in behavior or safety performance are difficult to demonstrate. Existing evaluation methods rely heavily on self-reported questionnaires and short-term observations, which may not capture subtle behavioral changes or long-term transfer to operational settings. Additionally, there is a lack of systematic feedback mechanisms, such as bottom-up assessments or team-level evaluations, that could support continuous learning and reinforcement of BRM principles (Htut, 2019). Without robust, context-sensitive assessment frameworks, the long-term effectiveness of BRM implementation in improving maritime safety culture remains constrained (Wahl & Kongsvik, 2018).

8. Future Directions for BRM.

In the future, we believe BRM should develop from a discrete training requirement into a continuous operational mindset that shapes how bridge teams function day by day. Rather than being treated as knowledge acquired during periodic courses, BRM should become embedded in routine watchkeeping, voyage planning, and decision-making processes. This means emphasizing adaptability, shared situational awareness, and reflective thinking as normal professional behaviors. By doing so, BRM would better support crews in handling uncertainty, operational variability, and unexpected situations, which are inevitable in modern maritime operations.

We also see the future of BRM placing greater emphasis on team-based learning and constructive feedback within the existing shipboard hierarchy. Training and development should focus on entire bridge teams, not just individuals, in order to strengthen communication patterns, trust, and mutual understanding among those who actually work together. At the same time, controlled feedback mechanisms should be encouraged so that leadership, teamwork, and communication can improve through learning rather than blame. As ships become more technologically advanced, BRM must also address how humans interact with automation, ensuring that responsibility, vigilance, and sound judgment remain central to safe navigation rather than being eroded by overreliance on systems.

9. Conclusion.

Based on the analysis of BRM throughout this study, it is clear to me that BRM remains a vital but still underutilized

element of maritime safety. While its principles are widely recognized and formally embedded in training and regulations, their practical application on board ships often falls short due to organizational hierarchy, individual-focused training, and limited feedback mechanisms. BRM, as currently implemented in many cases, tends to raise awareness rather than bring about sustained behavioral change. To truly enhance safety performance, BRM must move beyond compliance-driven instruction and become an integral part of daily bridge operations, leadership practice, and team interaction.

Overall, we conclude that the effectiveness of BRM is closely linked to how well it reflects real operational contexts and social dynamics on board ships. Communication, teamwork, and leadership cannot be treated as abstract skills, but must be continuously practiced, reinforced, and evaluated within the working environment. Without addressing these human and organizational dimensions, BRM risks remaining a theoretical framework with limited impact on actual navigational safety.

10. Recommendations.

For Maritime Authorities

- Authorities should embed BRM principles into Safety Management Systems (SMS) as an ongoing operational practice rather than a compliance formality.
- Regular refresh activities, linked to accidents and near-miss learning, should be encouraged on board.
- Guidance should also address human–automation interaction to maintain active human oversight.

For MET Institutions

- Training institutions should move beyond classroom-based BRM and prioritize scenario-driven, team - focused learning.
- Programs should emphasize realistic simulations, structured debriefings, and reflection on team behavior.
- Assessment should focus on observable skills such as communication, leadership, and decision making rather than theory alone.

For Shipping Companies / Ship Operators

- should actively reinforce BRM principles through daily operations, briefings, and bridge team practices.
- Companies are encouraged to foster an open communication culture that supports constructive feedback without blame.
- Regular evaluation of teamwork and leadership performance should be used to strengthen safety culture and operational resilience.

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