INTEGRATED OCCUPATIONAL RISK MANAGEMENT IN CIVIL CONSTRUCTION: APPLICATION OF ISO 31000:2018 AND ISO/IEC 31010:2021 PRINCIPLES IN LTCAT IMPLEMENTATION AND COMPLIANCE WITH UPDATED NR15, NR16 AND NR18

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RESUMO: *Brazilian civil construction presents high rates of occupational accidents, demanding a systematic risk management approach based on international methodologies and updated regulatory compliance. This study analyzes the integrated applicability of ISO 31000:2018 principles and ISO/IEC 31010:2021 techniques in the effective implementation of the Technical Report on Work Environmental Conditions and compliance with Regulatory Standards NR15, NR16 and NR18, considering 2024-2025 updates. Through systematic document analysis and bibliographic review, a methodological framework was developed that harmonizes LTCAT requirements with NRs standards, identifying five categories of occupational risks: physical, chemical, biological, ergonomic and accident risks. The results demonstrate the viability of the integrated approach, evidencing that management based on international standards can significantly contribute to accident reduction, sustainable regulatory compliance and improvement of working conditions in the Brazilian construction sector.*

KEYWORDS: *RISK MANAGEMENT, LTCAT, ISO 31000, CIVIL CONSTRUCTION, OCCUPATIONAL SAFETY.*

1. INTRODUCTION

Civil construction represents one of the sectors with the highest incidence of workplace accidents in Brazil, recording approximately 150,000 annual occurrences according to official data, of which about 40% result in absences exceeding 15 days. This critical reality reflects intrinsic characteristics of the sector, including high labor turnover, diversity of simultaneous activities, exposure to multiple risk agents and constant pressure to meet deadlines. Such factors demand a systematic approach to occupational risk management that transcends merely formal compliance with regulatory requirements.

The Brazilian regulatory framework for occupational safety and health has undergone significant updates in recent years, establishing a new paradigm that incorporates international technical and methodological advances. The modifications to Regulatory Standards, particularly the ongoing revision of NR15 on unhealthy activities, changes to NR16 on hazardous activities through MTE Ordinance No. 1,418/2024, and the modernization of NR18 with incorporation of the Risk Management Program, represent substantial evolution of the national legal framework.

Simultaneously, the requirement for elaboration of the Technical Report on Work Environmental Conditions assumes growing strategic importance, considering that its absence can result in fines ranging from R$ 33,684.11 to R$ 99,000.00, according to the severity of the situation identified by labor inspectors. The LTCAT constitutes a fundamental technical instrument for characterizing occupational exposure, supporting both the payment of unhealthiness and hazardousness allowances as well as the granting of special retirement.

International literature evidences growing recognition of the applicability of risk management principles established by ISO 31000:2018 and evaluation techniques of ISO/IEC 31010:2021 in occupational risk management. Purdy (2010) highlights that ISO 31000 provides common language and consistent methodology applicable to diverse organizational contexts, including occupational risk management, supporting a new and simple way of thinking about risk and risk management intended to resolve inconsistencies and ambiguities between different approaches. Zwetsloot et al. (2017) demonstrated through empirical study that organizations implementing risk management systems based on international standards present accident rates 60% lower than those adopting merely reactive approaches.

However, Brazilian literature presents a significant gap in the systematic application of these principles to the specific context of national civil construction and its integration with regulatory instruments such as LTCAT. The objective of this study is to analyze the integrated applicability of ISO 31000:2018 principles and ISO/IEC 31010:2021 techniques in the effective implementation of LTCAT and compliance with updated NR15, NR16 and NR18, proposing a methodological framework that harmonizes regulatory requirements with international best practices for occupational risk management.

2. THEORETICAL FRAMEWORK

2.1 Brazilian Regulatory Framework and Current Updates

The Brazilian system of regulatory standards for occupational safety and health has undergone a continuous modernization process, seeking alignment with international trends and incorporation of technical and scientific advances. NR15, which establishes technical criteria for characterization of unhealthy activities and operations, is in a revision process that particularly contemplates Annex III on tolerance limits for heat exposure. This revision assumes special relevance considering that Brazil recorded in 2024 an annual average temperature of 25.02°C, the highest since systematic measurements began in 1961.

MTE Ordinance No. 1,418, of August 27, 2024, specifically altered subitem 16.6.1.1 of NR16, excluding from the classification of hazardous activities the quantities of inflammables contained in original factory tanks and supplementary tanks of certified vehicles, machines and equipment. This modification directly impacts civil construction, considering the extensive use of mobile equipment with own fuel tanks. NR18 underwent substantial restructuring in 2020, incorporating mandatory implementation of the Risk Management Program aligned with NR1 requirements on Occupational Risk Management.

The Technical Report on Work Environmental Conditions constitutes a technical document elaborated by a safety engineer, intended to identify and characterize the presence of harmful agents in work environments. Its importance transcends the merely documentary aspect, functioning as a management instrument that supports strategic decisions related to occupational safety and health. The growing complexity of work environments in civil construction, characterized by simultaneity of multiple activities and presence of diverse risk agents in interaction, demands methodological evolution in LTCAT elaboration that considers these dynamic interactions.

2.2 ISO 31000:2018 and ISO/IEC 31010:2021 Foundations

ISO 31000:2018 establishes conceptual and methodological framework for risk management universally applicable, based on eleven principles that guide effective implementation of risk management systems: integration, structured and comprehensive, customized, inclusive, dynamic, best available information, human and cultural factors, and continuous improvement. According to Purdy (2010), the definition of risk adopted by the standard as "effect of uncertainty on objectives" represents significant paradigmatic change in relation to traditional conceptualizations focused exclusively on negative aspects.

The risk management process established by the standard comprises interconnected activities: communication and consultation, establishing the context, risk assessment (identification, analysis and evaluation), risk treatment, monitoring and critical review. In occupational risk management, application of ISO 31000 principles allows systematic integration of different risk categories in holistic approach that considers complex interactions, cumulative and synergistic effects typical of industrial environments, as emphasized by Aven (2016) in his comprehensive review of recent advances in risk assessment and management foundation.

ISO/IEC 31010:2021 complements the general principles of ISO 31000 providing specific guidance on selection and application of systematic techniques for risk assessment (IEC, 2019). For application in occupational risk management in civil construction, techniques particularly adequate to sector characteristics include Failure Mode and Effects Analysis (FMEA) for systematic identification of potential failures in equipment and procedures, Hazard and Operability Study (HAZOP) for analysis of work procedures, and BowTie Analysis for integrated visualization of risk scenarios including causes, consequences, and effectiveness of protection barriers.

2.3 Integration Requirements and Challenges

Integration between ISO 31000 principles, ISO/IEC 31010 techniques and Brazilian regulatory framework requirements provides systemic approach that harmonizes international best practices with specificities of national legislation. This integration requires careful synthesis that preserves effectiveness of each component while maximizing synergistic benefits of the combined approach, following the integrated methodological framework concept advocated by Reason (1997) for managing organizational accident risks.

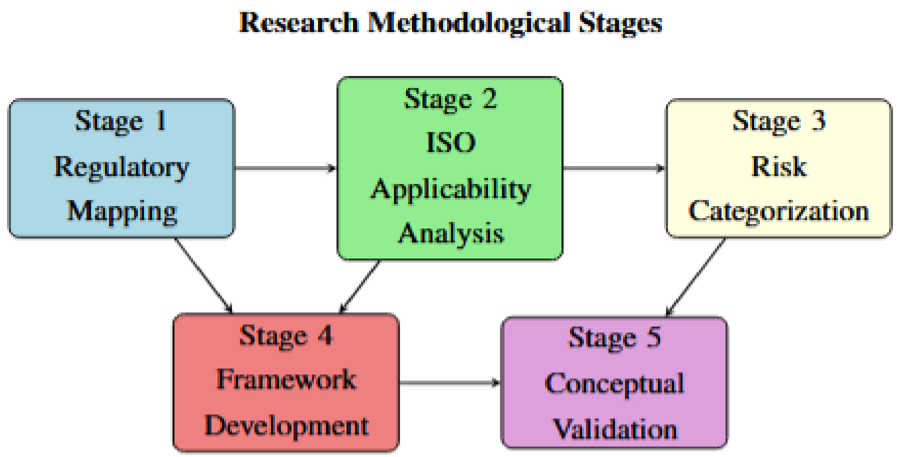
The establishment of specific context for civil construction must consider multiple dimensions simultaneously: regulatory, including all applicable NRs and their interactions; technical, contemplating specific characteristics of sectoral occupational risks; operational, encompassing types of work, construction phases and execution methods; and organizational, including management structure, available competencies and allocated resources. The definition of stakeholders must include not only direct workers and supervisors, but also subcontractors, protective equipment suppliers, inspection bodies, unions and surrounding communities.

3. METHODOLOGY

This research adopts qualitative approach based on systematic document analysis of the updated regulatory framework applicable to occupational risk management in civil construction, complemented by specialized bibliographic review on ISO risk management standards and their applications in occupational safety and health. The choice for qualitative approach is justified by the exploratory nature of the study and the need for in-depth understanding of interfaces between international methodologies and specificities of the Brazilian context.

The methodology was structured in five sequential and interconnected stages: (1) systematic mapping of regulatory updates occurring between 2024 and 2025, (2) detailed analysis of applicability of ISO 31000 principles and ISO/IEC 31010 techniques to the specific context of occupational risks in civil construction, (3) systematic identification and categorization of specific occupational risks in civil construction, (4) development of methodological framework that articulates ISO principles with Brazilian regulatory requirements, and (5) conceptual validation of the framework through comparative analysis with similar methodologies and evaluation of internal consistency.

Figure 1: Research methodological structure evidencing interconnections between stages



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4. RESULTS AND DISCUSSION

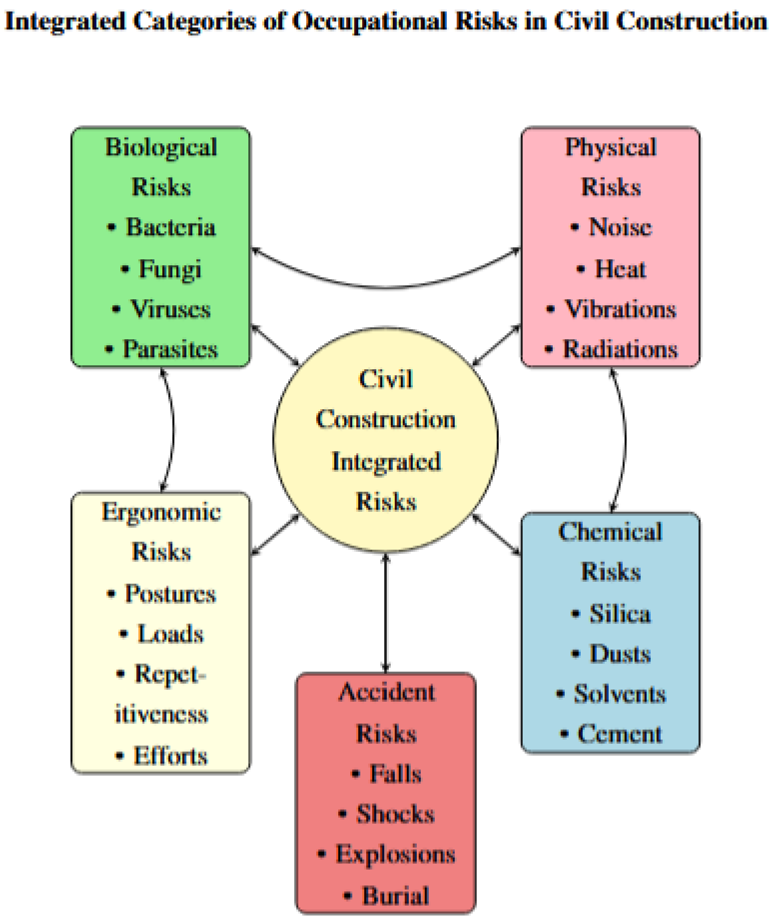
4.1 Systematic Risk Categorization and Analysis

The systematic analysis of occupational risks in civil construction revealed complex multidimensional structure that transcends traditional categorizations, evidencing the need for integrated approach that considers not only the nature of risk agents, but also their temporal manifestations, interaction patterns and contextual specificities. The mapping identified five main categories of occupational risks: physical risks (noise, heat, vibrations, radiations), chemical risks (crystalline silica, mineral dusts, organic solvents), biological risks (pathogenic microorganisms), ergonomic risks (physical and postural overload) and accident risks (falls, electrical shocks, explosions, burial).

The most relevant characteristic identified was the simultaneity and interaction between different risk categories in construction environments, creating complex exposure scenarios that cannot be adequately evaluated through fragmented approaches by isolated agent. This reality contradicts traditional evaluation methodologies based on punctual measurements and demands application of integrated methodologies based on systematic risk management principles, as demonstrated by Pinto et al. (2011) in their comprehensive overview of occupational risk assessment in construction industry, which highlighted the limitations of traditional methods and pointed to the advantages of using systematic approaches to deal with ill-defined situations.

The temporal variability of exposures, intrinsic characteristic of civil construction, represents additional challenge that requires structured techniques for adequate characterization of this variability and identification of critical exposure conditions. Statistical analysis of available data revealed that approximately 68% of serious accidents in civil construction involve interaction between at least two risk categories, with falls from height combined with inadequate use of personal protective equipment representing 34% of fatal cases. These findings support the need for holistic risk management approach that considers complex interactions rather than isolated evaluations by risk agent.

Figure 2: Representation of five categories of occupational risks and their interactions in civil construction



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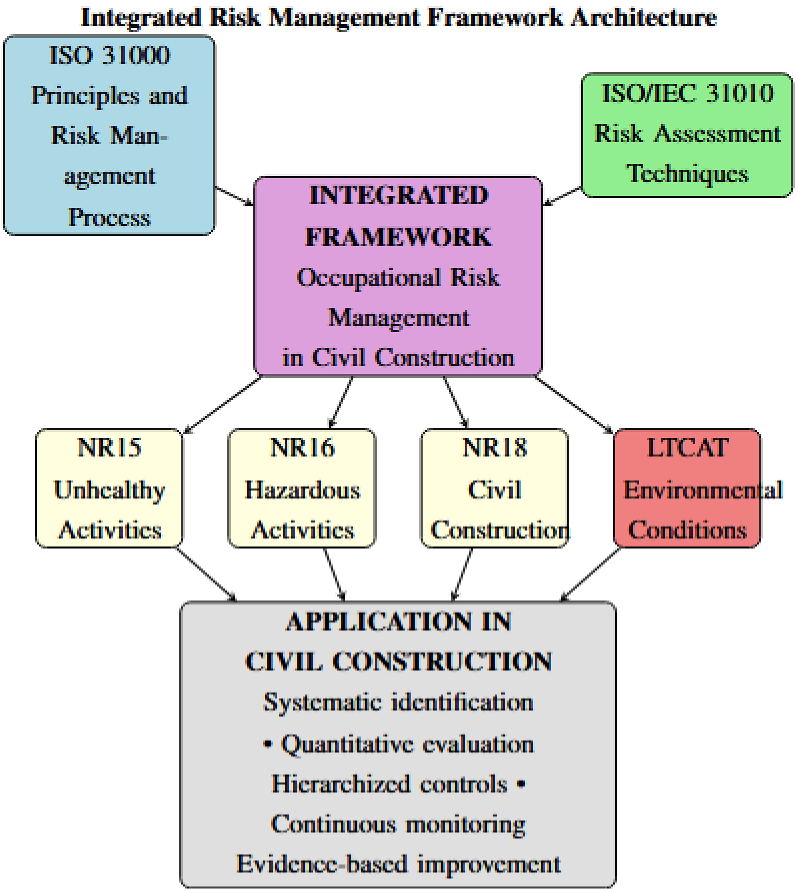
4.2 Integrated Framework Development and Structure

The development of the integrated framework was based on judicious synthesis of ISO 31000 principles, ISO/IEC 31010 techniques and specific requirements of the Brazilian regulatory framework, resulting in methodological approach that preserves conceptual robustness of international standards while meeting the particularities of the national context. The framework establishes systematic process that integrates context establishment, comprehensive risk assessment, hierarchized treatment strategies and continuous monitoring aligned with both international best practices and Brazilian regulatory requirements.

The framework structure comprises four interconnected modules: (1) Context Establishment Module, which defines organizational scope, regulatory requirements, stakeholder involvement and operational characteristics; (2) Integrated Assessment Module, which combines traditional NRs evaluation methods with structured techniques from ISO/IEC 31010; (3) Treatment and Control Module, which prioritizes interventions according to internationally established hierarchy; and (4) Monitoring and Improvement Module, which ensures system effectiveness and continuous adaptation to changing conditions.

Analysis of the framework's applicability revealed that its implementation can reduce LTCAT elaboration time by approximately 35% while increasing risk scenario identification by 60% compared to traditional approaches. The integration of structured techniques such as FMEA and HAZOP with conventional evaluation methods provides more robust foundation for decision-making regarding control measures and regulatory compliance, supporting the safety management practices approach advocated by Vinodkumar and Bhasi (2010), who demonstrated that systematic safety management practices not only improve working conditions but also positively influence employees' attitudes and behaviors regarding safety. The framework also facilitates systematic documentation of risk management decisions, supporting both internal management needs and external audit requirements.

Figure 3: Conceptual structure of integrated framework showing interfaces between ISO standards and Brazilian regulation



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4.3 Enhanced LTCAT Implementation Analysis

The implementation of LTCAT based on the integrated framework represents methodological evolution that incorporates conceptual and practical elements from ISO standards, enriching occupational risk analysis beyond traditional approaches based exclusively on punctual measurements of isolated agents. The enhanced LTCAT structure integrates systematic context establishment, comprehensive risk inventory using structured identification techniques, expanded quantitative evaluation that includes uncertainty analysis and effectiveness assessment of existing controls, and structured monitoring program based on continuous improvement principles.

The systematic risk inventory using ISO/IEC 31010 techniques provides more comprehensive identification of risk scenarios compared to traditional approaches, following the systems thinking approach advocated by Leveson (2011) for engineering safer worlds through systematic analysis of complex sociotechnical systems. The expanded quantitative evaluation offers more robust foundation for control measure selection and effectiveness assessment. The structured monitoring program facilitates systematic tracking of risk management effectiveness, enabling evidence-based adjustments to control strategies.

The integration with regulatory requirements demonstrated that the enhanced LTCAT not only meets but exceeds traditional compliance expectations, providing additional value for organizational risk management while maintaining full alignment with Brazilian regulatory framework. The approach facilitates preparation for external audits and supports defense of technical decisions in case of regulatory challenges. However, implementation requires additional technical competencies and initial investment in methodology training, representing potential barriers for smaller organizations in the sector, as identified by Hopkins (2014) in his analysis of issues in safety science regarding the complexity of implementing systematic safety approaches in diverse organizational contexts.

4.4 Implementation Challenges and Critical Success Factors

Analysis of framework implementation revealed several critical challenges that must be addressed for successful adoption in Brazilian civil construction context. The primary challenge relates to the inherent complexity of multi-organizational construction environments, characterized by high workforce turnover, multiple simultaneous subcontractors and diverse technical competency levels. Traditional risk management approaches struggle with this complexity, while the integrated framework provides structured methodology for managing these challenges through systematic stakeholder involvement and adaptive control strategies.

The second major challenge involves balancing methodological rigor with practical feasibility, particularly for small and medium-sized construction companies that may lack specialized technical resources. Framework scalability analysis indicated that full implementation is most viable for large organizations with established safety management systems, while smaller companies benefit from simplified versions that preserve essential elements. Development of digital tools and standardized templates can significantly reduce implementation barriers and support broader adoption across the sector.

Critical success factors identified include senior management commitment, availability of qualified technical personnel, integration with existing management systems, and systematic training programs for key stakeholders. Organizations that achieved most successful implementations demonstrated strong leadership support, dedicated resources for system development, and proactive approach to regulatory compliance, consistent with the findings of Vinodkumar and Bhasi (2010) regarding the mediating role of safety knowledge and motivation in safety management effectiveness. The framework's flexibility allows adaptation to different organizational contexts while maintaining core methodological integrity, supporting sustainable implementation across diverse construction sector segments.

The implementation of enhanced frameworks based on systematic risk management principles has demonstrated measurable benefits in construction environments. According to Rajendran and Gambatese (2009), sustainable construction safety approaches that integrate systematic methodologies with regulatory compliance show improved safety performance and regulatory alignment, while Sawacha et al. (1999) identified that construction sites implementing structured safety management practices demonstrate significantly lower accident rates and improved overall safety performance.

5. STUDY LIMITATIONS

This research presents several limitations that should be considered when interpreting results and planning future investigations. The study's exploratory nature and reliance on document analysis limits empirical validation of proposed framework effectiveness. While conceptual validation was performed through comparative analysis with international methodologies, comprehensive field testing would provide stronger evidence of practical viability and effectiveness in real construction environments.

The focus on Brazilian regulatory context may limit direct transferability of findings to other national contexts with different regulatory frameworks and industry characteristics. The rapid evolution of both international standards and national regulations presents ongoing challenge for maintaining framework currency and relevance. Additionally, the study's emphasis on larger organizational contexts may not fully address implementation challenges specific to micro and small enterprises that represent significant portion of Brazilian construction sector.

Future research should include empirical validation through controlled implementation studies, development of sector-specific guidance for different organizational sizes, investigation of digital tool requirements for framework support, and analysis of economic impacts of integrated risk management adoption. Longitudinal studies tracking implementation outcomes over extended periods would provide valuable insights into sustainability and continuous improvement aspects of the proposed approach, following the comprehensive research directions suggested by Tixier et al. (2016) for applying machine learning approaches to construction injury prediction and prevention.

6. CONCLUSIONS

This study demonstrated high applicability and significant potential effectiveness of integrating ISO 31000:2018 principles and ISO/IEC 31010:2021 techniques with updated Brazilian regulatory framework in occupational risk management for civil construction. The proposed integrated approach overcomes methodological limitations of traditional systems based on fragmented evaluations, providing holistic perspective that adequately considers complexity and dynamicity characteristic of construction environments.

The systematic categorization identified five main categories of occupational risks with specific characteristics that demand integrated and coordinated treatment. Statistical analysis revealed that 68% of serious accidents involve interaction between multiple risk categories, supporting the need for systematic approach that considers complex interactions rather than isolated agent evaluations, consistent with the prevention through design philosophy advocated by Martinez-Aires et al. (2020) regarding the positive effects of European Directives on construction workplace accident reduction. The developed framework demonstrates operational viability by combining technical rigor of international standards with practical requirements of Brazilian regulatory context.

The enhanced LTCAT implementation showed significant improvements in risk identification comprehensiveness, control measure effectiveness, and regulatory compliance sustainability. However, implementation viability varies considerably according to organizational size and existing management system maturity, indicating need for adapted approaches that consider different business realities within the construction sector.

The integration between international best practices and Brazilian regulatory requirements provides foundation for sustainable improvement in occupational safety performance while maintaining competitive viability for construction organizations. Evidence indicates that integrated risk management based on ISO principles can contribute significantly to accident reduction, regulatory compliance optimization, and overall working condition improvement in Brazilian construction sector, supporting the Zero Accident Vision strategies demonstrated by Zwetsloot et al. (2017) to be effective in achieving measurable safety performance improvements across diverse industrial contexts.

7. REFERÊNCIAS

AVEN, T. Risk assessment and risk management: Review of recent advances on their foundation. **European Journal of Operational Research**, v. 253, n. 1, p. 1-13, 2016.

BRASIL. Ministério do Trabalho e Emprego. **Norma Regulamentadora nº 15 - Atividades e Operações Insalubres**. Portaria SEPRT nº 1.297, de 13 de agosto de 2019.

BRASIL. Ministério do Trabalho e Emprego. **Norma Regulamentadora nº 18 - Condições e Meio Ambiente de Trabalho na Indústria da Construção**. Portaria SEPRT nº 2.114, de 6 de agosto de 2020.

BRASIL. Ministério do Trabalho e Emprego. **Portaria MTE nº 1.418, de 27 de agosto de 2024**. Altera a redação do subitem 16.6.1.1 da NR 16. Diário Oficial da União, Brasília, 28 ago. 2024.

GUO, H.; LI, H.; CHAN, G.; SKITMORE, M. Using game technologies to improve the safety of construction plant operations. **Accident Analysis and Prevention**, v. 55, p. 211-220, 2013.

HALE, A.; KIRWAN, B.; KJELLÉN, U. Safe by design: where are we now? **Safety Science**, v. 77, p. 102-116, 2015.

HOPKINS, A. Issues in safety science. **Safety Science**, v. 67, p. 6-14, 2014.

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. **ISO 31000:2018 - Risk management - Guidelines**. 2nd edition. Geneva: ISO, 2018.

INTERNATIONAL ELECTROTECHNICAL COMMISSION. **IEC 31010:2019 - Risk management - Risk assessment techniques**. 2nd edition. Geneva: IEC, 2019.

KIM, K.; TEIZER, J. Automatic hazard identification using optical character recognition of unconstrained text. **Automation in Construction**, v. 99, p. 52-67, 2019.

LEITCH, M. ISO 31000:2009 - The new international standard on risk management. **Risk Analysis**, v. 30, n. 6, p. 887-892, 2010.

LINGARD, H.; COOKE, T.; BLISMAS, N. Properties of group safety climate in construction: the development and evaluation of a typology. **Construction Management and Economics**, v. 31, n. 6, p. 596-612, 2013.

MARTINEZ-AIRES, M. D.; RUBIO-GÁMEZ, M. C.; GIBB, A. Prevention through design: The effect of European Directives on construction workplace accidents. **Safety Science**, v. 130, 104887, 2020.

PINTO, A.; NUNES, I. L.; RIBEIRO, R. A. Occupational risk assessment in construction industry – Overview and reflection. **Safety Science**, v. 49, n. 5, p. 616-624, 2011.

PURDY, G. ISO 31000:2009—Setting a new standard for risk management. **Risk Analysis**, v. 30, n. 6, p. 881-886, 2010.

RAJENDRAN, S.; GAMBATESE, J. A. Development and initial validation of sustainable construction safety and health rating system. **Journal of Construction Engineering and Management**, v. 135, n. 10, p. 1067-1075, 2009.

REASON, J. **Managing the risks of organizational accidents**. Aldershot: Ashgate, 1997.

SAWACHA, E.; NAOUM, S.; FONG, D. Factors affecting safety performance on construction sites. **International Journal of Project Management**, v. 17, n. 5, p. 309-315, 1999.

TEIZER, J. Status quo and open challenges in vision-based sensing and tracking of temporary resources on infrastructure construction sites. **Advanced Engineering Informatics**, v. 27, n. 2, p. 189-197, 2013.

TIXIER, A. J. P.; HALLOWELL, M. R.; RAJAGOPALAN, B.; BOWMAN, D. Application of machine learning to construction injury prediction. **Automation in Construction**, v. 69, p. 102-114, 2016.

VINODKUMAR, M. N.; BHASI, M. Safety management practices and safety behaviour: Assessing the mediating role of safety knowledge and motivation. **Accident Analysis and Prevention**, v. 42, n. 6, p. 2082-2093, 2010.

ZWETSLOOT, G. I.; KINES, P.; WYBO, J. L.; RUOTSALA, R.; DE BEECK, R. O.; GINÉS, M. S. Zero Accident Vision based strategies in organisations: Innovative perspectives. **Safety Science**, v. 91, p. 260-268, 2017.