Safety management is an essential subject in the process industry since accidents in this domain can have severe social, economic, and environmental consequences. Maintenance activities with functions for early fault detection are a critical part of the safety management system in the process industry.

Maintenance activities in the process industry often involve hazardous working conditions with high temperatures, low-quality air, and high physical demand. In the background of Industry 4.0, robot automation is introduced to maintenance operations to try to release human operators from tedious, repeated physical work and dangerous operations in maintenance activities. Human operators still need to be in the loop because of their ability to be more flexible and have a better strategic view. Therefore, human-robot collaborative teaming (HRT) operations will be a primary paradigm.

HRT operations involving multiple twisted elements are complex socio-technical systems for which previous methods that only focus on the technical or social part are not sufficient. These complex systems require a novel integrated framework able to consider human and organizational factors (HOFs), technical factors, as well as their interdependence.

Through data analysis of accident reports from eMARS, the most contributing organizational factors in HOFs and maintenance-related accidents were identified. Therefore, the Cognitive Reliability and Error Analysis Method (CREAM), which contains all these contributing organizational factors in the form of common performance conditions (CPCs), is selected to perform the HRA part in the integrated framework in an extended way.

After reviewing the literature on probability risk assessment, HRA, organizational factors, and complex system theory.
The integrated risk-based performance assessment framework is proposed. This framework contains a qualitative phase employing the top-down approach and a quantitative phase employing the bottom-up approach. The outputs of the first phase include a qualitative task analysis list supporting HRT team structure transitions analysis and task logical interdependence analysis. Then, the outputs of the second phase include quantitative risks and performance indicator values supporting system performance comparison and critical scenarios and factors analysis.

The proposed framework was demonstrated step-by-step in a case study of LPG spherical storage tank inspection in the full manual (FM) and HRT operations. The system performance of these two scenarios was compared. The results show the evolution in terms of the systemic performance from the FM to the HRT system. Also, the boundaries of critical factors were calculated. The quantitative results could provide better insights to support decision-making about HRT operation in practice. The framework validated is able to give guild to risk and performance assessment for complex socio-tech systems. Further work could be performed to extend the model with a reinforcement learning algorithm to optimize the robot paths and HRT schedule.