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Integrating HAZOP LOPA and QRA into the Management of Change Process

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PUBLICATION NOTE

This paper presents an illustrative risk-based framework. It does not replace applicable regulations, company procedures, risk criteria, or project-specific engineering judgement.

EXECUTIVE SUMMARY

Management of Change (MOC) prevents modifications from introducing unmanaged process-safety risk, but the MOC procedure must also determine the depth of hazard evaluation appropriate to each change.

This paper shows how Hazard and Operability Study (HAZOP), Layer of Protection Analysis (LOPA), and Quantitative Risk Assessment (QRA) can be integrated through screening, analysis, authorization, implementation, and startup. HAZOP identifies deviations and safeguard gaps; LOPA tests whether defined scenarios have adequate independent protection; and QRA combines scenario frequencies and consequences to estimate risk to defined receptors.

The central requirement is traceability: study selection must be justified, assumptions must be reconciled between methods, actions necessary for safe startup must be verified, and the approved risk basis must become part of the facility record.

1. PURPOSE AND SCOPE

This paper provides a practical governance framework for selecting and connecting HAZOP, LOPA, and QRA during MOC. The framework is intended for process-industry modifications involving hazardous materials, process conditions, control systems, safety instrumented systems, occupied buildings, or emergency-response arrangements.

The proposed tiers are illustrative. Each organization should align its thresholds and required studies with applicable law, its MOC procedure, corporate risk criteria, technical-authority requirements, and the maturity of available design information.

2. HOW THE THREE METHODS COMPLEMENT EACH OTHER

HAZOP is a structured, multidisciplinary guide-word examination of deviations, causes, consequences, existing safeguards, and recommendations. LOPA evaluates a defined initiating event and consequence scenario identified through HAZOP or another suitable hazard-identification method. It applies approved initiating-event frequencies, conditional modifiers, and qualifying independent protection layers (IPLs) to compare the mitigated event likelihood with a company criterion. Where additional risk reduction is assigned to a safety instrumented function (SIF), the required SIL becomes an input to the functional-safety lifecycle.

QRA uses modelled scenario frequencies and consequences to estimate risk to defined receptors. Results may include individual-risk contours, societal-risk measures, location-specific risk, impairment frequencies, or other project-specific metrics. QRA is quantitative and model based, but its outputs remain dependent on scenario definition, data quality, modelling assumptions, occupancy, vulnerability, and the selected risk criteria.

Approach	HAZOP	LOPA	QRA
Primary question	What can deviate and what may happen?	Is protection adequate for this defined scenario?	What risk results from the combined scenario set?
Unit of analysis	Node and deviation	Initiating event and consequence scenario	Multiple scenarios and exposed receptors
Typical output	Causes, consequences, safeguards and actions	Mitigated likelihood, risk gap and possible SIL requirement	Risk measures, contours and decision support
Key limitation	Does not normally quantify risk	Sensitive to scenario and IPL assumptions	Sensitive to modelling scope, data and uncertainty

Table 1. Functional relationship between HAZOP, LOPA, and QRA.

3. INTEGRATION THROUGH THE MOC LIFECYCLE

A robust MOC treats hazard evaluation as a controlled thread rather than a single workshop. In a US OSHA PSM context, the MOC record should address the technical basis for the change, safety and health impacts, required procedure changes, the necessary time period, and authorization requirements. Affected employees and contractors must be informed and trained before startup, and process safety information and operating procedures must be updated where affected.

Lifecycle stage	Minimum control expectation
1. Define	Describe the technical basis, boundaries, duration, affected equipment, materials, controls and operating modes. Distinguish permanent, temporary, emergency, and replacement-in-kind changes.
2. Screen	Assign the base tier and apply escalation triggers. Record the rationale and obtain independent process-safety or technical-authority confirmation.
3. Analyze	Select the proportionate hazard-evaluation method. Define scope, team competence, assumptions, risk criteria, study interfaces and required deliverables.
4. Reconcile	Align HAZOP scenarios, LOPA definitions, QRA assumptions, SIS requirements, occupied-building assessments, human factors and emergency-response impacts.
5. Authorize	Document residual risk, action ownership, safe-startup requirements and any formally approved deferments supported by interim controls and completion dates.
6. Implement	Update drawings, process safety information, procedures, training, inspection and maintenance plans, alarms, SIS documentation and emergency arrangements.
7. Verify and learn	Complete the applicable PSSR, validate safeguards, confirm safe-startup actions, update the risk baseline and perform post-implementation review.

Table 2. Hazard evaluation as a controlled thread through MOC.

4. STUDY HANDOFF AND ASSUMPTION CONTROL

The methods should share traceable scenario identifiers, but their numerical inputs should not be transferred without review. LOPA and QRA can use different scenario endpoints, initiating-event frequencies, ignition and occupancy assumptions, vulnerability models, conditional modifiers, and safeguard-credit rules. Directly inserting a mitigated LOPA frequency into QRA can therefore create inconsistency or double counting.

- Use a common scenario register linking equipment, node, cause, consequence, safeguard, action, and model reference.
- Reconcile frequency, consequence, dependency, conditional-probability, occupancy, and vulnerability assumptions between LOPA and QRA.
- Credit only safeguards that satisfy the organization’s IPL rules for independence, effectiveness, response time, specificity, and auditability.
- Use sensitivity and uncertainty checks when a risk decision depends on uncertain or generic inputs.
- Retain version control so the approved QRA, LOPA, P&IDs, cause-and-effect diagrams, and SIS documents describe the same design state.

5. ILLUSTRATIVE RISK BASED SCREENING FRAMEWORK

The following framework contains four principal tiers and a Tier 2+ escalation trigger. It is a governance example, not a universal standard. The final method selection should consider credible consequence, novelty, complexity, uncertainty, affected safeguards, cumulative risk, regulatory requirements, and proximity to people or sensitive receptors.

Classification	Indicative characteristics	Minimum evaluation
Tier 0 Administrative	Verified replacement in kind with no design-basis change	Replacement-in-kind checklist and technical confirmation
Tier 1 Focused review	Minor change within the approved design envelope	Document review plus focused What-If, checklist, or mini-HAZOP as appropriate
Tier 2 Standard	New equipment, chemistry, operating envelope, inventory, or multidisciplinary interfaces	Scoped HAZOP or equivalent PHA; LOPA for scenarios meeting company screening criteria
Tier 2+ Escalation	Change affects an SIS, SIF, credited IPL, trip, alarm, bypass, proof test, or common utilities	Functional-safety impact assessment and LOPA or equivalent risk review; lifecycle activities as applicable
Tier 3 Comprehensive	Potential material change to major-accident, occupied-building, environmental, on-site, or off-site risk	HAZOP or equivalent PHA, selected LOPA, and an appropriate QRA or consequence/risk-model update

Table 3. Illustrative risk-based screening framework.

6. ROLES AND GOVERNANCE

Role	Core responsibility
Change owner	Defines the technical basis, scope, duration, implementation plan and business need; does not self-approve the risk tier.
MOC coordinator	Administers workflow, maintains the integrated action register and confirms required documentation and approvals.
Process safety or technical authority	Confirms screening, study selection, competence, assumptions, risk criteria and technical closeout.
Operations and maintenance	Validate operating modes, human response, maintainability, testing, temporary arrangements and procedure changes.
HAZOP and LOPA leader	Provides competent facilitation, preserves scenario traceability and records limitations, assumptions and recommendations.
Functional safety authority	Controls SIF lifecycle requirements, independence, SRS changes, verification, validation, testing and assessment.
QRA lead	Defines model scope and uncertainty; reconciles scenarios and frequency assumptions with the broader risk record.
Authorizer or risk owner	Accepts residual risk within delegated authority and approves documented deferments and interim controls.
PSSR team	Verifies that the modification meets design intent and that requirements necessary for safe startup are complete.

Table 4. Representative responsibilities across MOC and hazard evaluation.

7. FUNCTIONAL SAFETY REQUIREMENTS FOR SIS CHANGES

A change to a SIF, SIS, sensor, logic solver, final element, trip set point, voting architecture, bypass, proof-test interval, common utility, or credited alarm should trigger a functional-safety impact assessment. A LOPA-derived SIL target is not the end of the analysis; it is an input to a controlled lifecycle.

- Revise the safety requirements specification and cause-and-effect documentation.
- Confirm independence from the initiating cause, BPCS, other credited IPLs, common utilities, and shared components.
- Verify architecture, systematic capability, probability of failure on demand or frequency of dangerous failure, process safety time, and common-cause assumptions.
- Plan validation, proof testing, bypass management, maintenance, competency, and functional safety assessment as applicable.
- Confirm that the as-built installation and operating arrangements match the verified design before startup.

8. WORKED EXAMPLE FLAMMABLE LIQUID TANK FARM CAPACITY INCREASE

ILLUSTRATIVE EXAMPLE

This simplified hypothetical example demonstrates workflow integration only. The distances, safeguards, SIL classification, and risk results are not design recommendations and must not be applied without project-specific analysis.

Step	Illustrative application
Change	Add two above-ground tanks containing a hypothetical NFPA Class IB flammable liquid within an existing diked or bunded area. The site boundary is approximately 180 m away and a permanently occupied control room approximately 220 m away.
Screening	The change increases hazardous inventory and may affect fire, explosion, occupied-building, and off-site risk. It is assigned illustrative Tier 3, with the Tier 2+ trigger applied because an existing overfill SIF may be extended.
HAZOP	The scoped HAZOP identifies tank overfill, an open dike drain, transfer overpressure, and loading-arm rupture during tanker unloading. It also reviews utilities, operating modes, common connections, drainage, ignition control, and emergency response.
Scenario screening	Tank overfill progresses to LOPA because of severe consequence and uncertainty over safeguard adequacy. The other scenarios are documented in a screening register and either progressed to LOPA, addressed by HAZOP actions, or included in QRA according to defined criteria.
LOPA	The high-level alarm receives credit only if the complete operator-response layer meets independence, effectiveness, response-time, and auditability requirements. A hypothetical SIL 2 high-high-level shutdown is treated as a proposed or modified SIF subject to the functional-safety lifecycle.
QRA	The facility QRA is updated with representative releases, revised inventory and operating frequencies. LOPA and QRA assumptions are reconciled rather than transferred automatically. Individual and societal risk, occupied-building exposure, and uncertainty are evaluated against site criteria.

Occupied building	An individual-risk contour alone does not demonstrate control-room structural adequacy. Applicable fire, blast and toxic loads are evaluated separately through consequence and occupied-building assessments.
MOC decision	Approval is conditional on SIF lifecycle completion, dike and drainage verification, occupied-building findings, procedure and emergency-plan updates, training, and closure of requirements necessary for safe startup. The approved QRA and action record become the new controlled baseline.

Table 5. Hypothetical Tier 3 MOC example.

9. MINIMUM CONTROLLED RECORD

Record group	Minimum content
MOC basis	Change description, technical basis, boundaries, duration, classification and affected assets.
Screening	Tier decision, escalation triggers, method-selection rationale and technical-authority approval.
Study record	HAZOP or PHA worksheets, LOPA sheets, QRA update, common scenario register, assumptions and limitations.
Functional safety	SRS updates, SIL verification, architecture and independence assessments, validation, proof-test and assessment records.
Implementation	Approved drawings, process safety information, procedures, training, inspection, maintenance and emergency-plan changes.
Actions	Integrated action register identifying safe-startup items, responsible persons, due dates, evidence and authorized deferments.
Startup and closeout	PSSR record where applicable, safeguard testing, startup authorization, post-implementation review and updated baseline.

Table 6. Minimum controlled MOC record for higher-tier changes.

10. COMMON FAILURE MODES

- Treating the illustrative tier table as a substitute for company-specific criteria or regulatory review.
- Allowing the change originator to self-assign the tier without independent technical confirmation.
- Using consequence severity as the sole LOPA trigger or failing to record why scenarios were excluded.
- Crediting alarms, relief devices, SIS functions, procedures, or containment as IPLs without verifying qualification and independence.
- Transferring mitigated LOPA frequencies into QRA without reconciling endpoints, dependencies and conditional modifiers.
- Using an individual-risk contour to claim occupied-building fire or blast adequacy.
- Treating SIL verification as the complete functional-safety lifecycle for an SIS modification.
- Keeping hazard-study actions outside the MOC record or allowing startup-critical requirements to remain unresolved.
- Failing to update procedures, training, process safety information, testing, emergency response, or the facility risk baseline.

11. CONCLUSION

HAZOP, LOPA, and QRA answer different questions and should be connected through controlled interfaces. HAZOP identifies credible deviations and safeguard gaps. LOPA tests the adequacy of protection for selected scenarios. QRA combines scenario frequency and consequence information to support facility-level decisions for defined receptors. Their value within MOC depends less on applying every method to every change than on selecting proportionate studies, reconciling assumptions, assigning competent ownership, and maintaining traceability through implementation and safe startup.

For significant modifications, the approved hazard evaluation should become part of the living process-safety basis. Future changes can then be screened against a current and auditable risk picture rather than against disconnected historical studies.

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