CFD-based evaluation of inherently safer FPSO layouts

IChemE Hazards 33, 7th November 2023

Etienne Guinot, Laurent Paris, Josue Quilliou

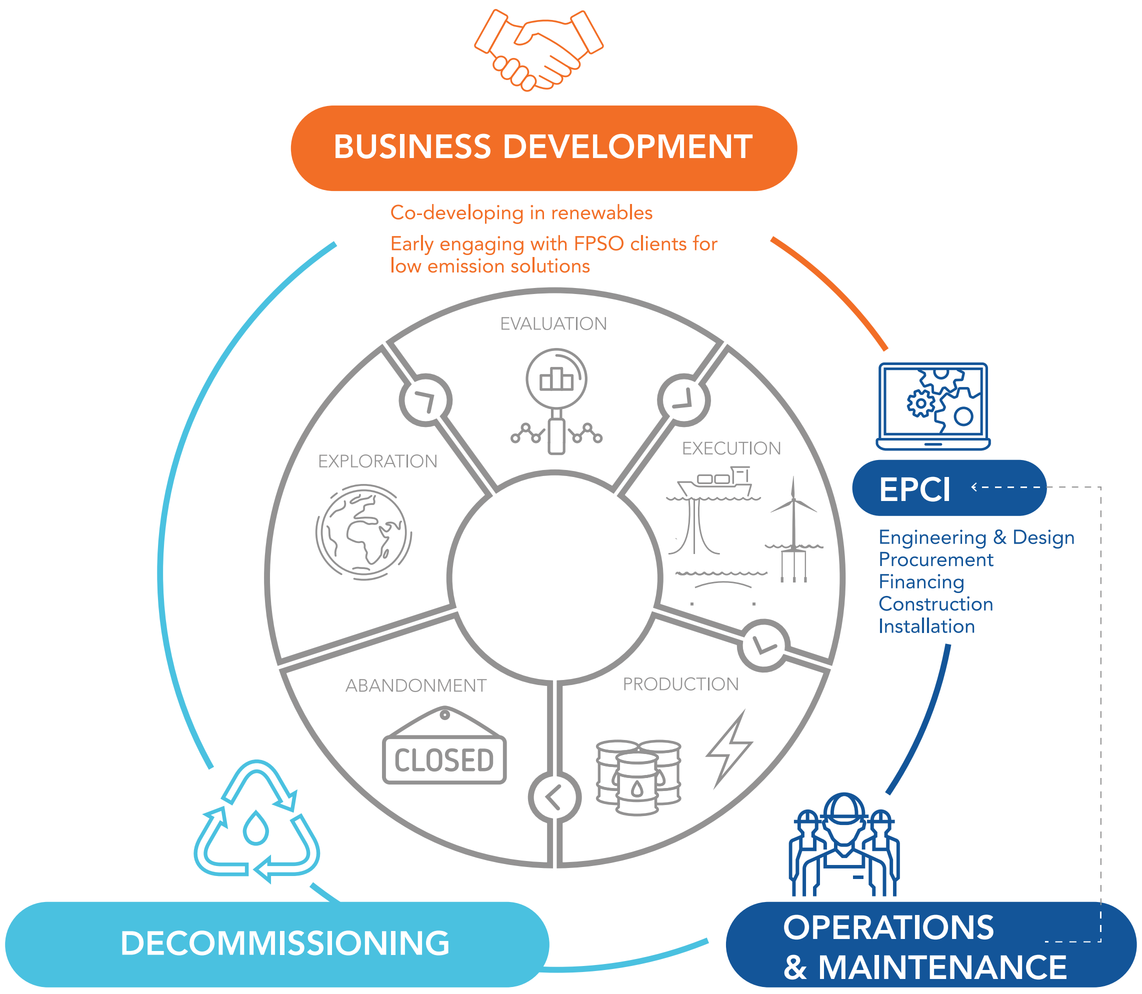
Contents

Full Product Lifecycle

SBM Offshore is unique in offering floating offshore energy solutions across the full product lifecycle, from the engineering and design, to offshore operations, through to the end of life of a vessel.

We proactively support our clients through long-term relationships over the lifespan of each vessel. Because each stage of the process informs all the others, we can deliver superior results and drive efficiencies.

- **EPCI: Engineering** and design is delivered through in-house resources. Procurement of equipment and services is a substantial component of projects. **Construction** is outsourced through agreements with qualified yards. **Installation** is carried out using specialized installation vessels.
- **Operations & Maintenance**: For FPSOs designed and built by SBM Offshore, operation and maintenance services are provided for clients.
- **Decommissioning and recycling**: At the end of the lifecycle, facilities are decommissioned and recycled. SBM Offshore applies the Hong Kong Convention rules and the principles of the EU Ship Recycling Regulation or equivalent.



© SBM Offshore 2023. All rights reserved. www.sbmoffshore.com

1. Introduction

Offshore industry context

- Deep offshore, no or limited existing infrastructures for oil / gas export
- Increasing required production capacities > 200 kBOPD
- Large gas handling capacities > 400 MMSCFD
- Fast-tracking large developments

Hazard management challenges

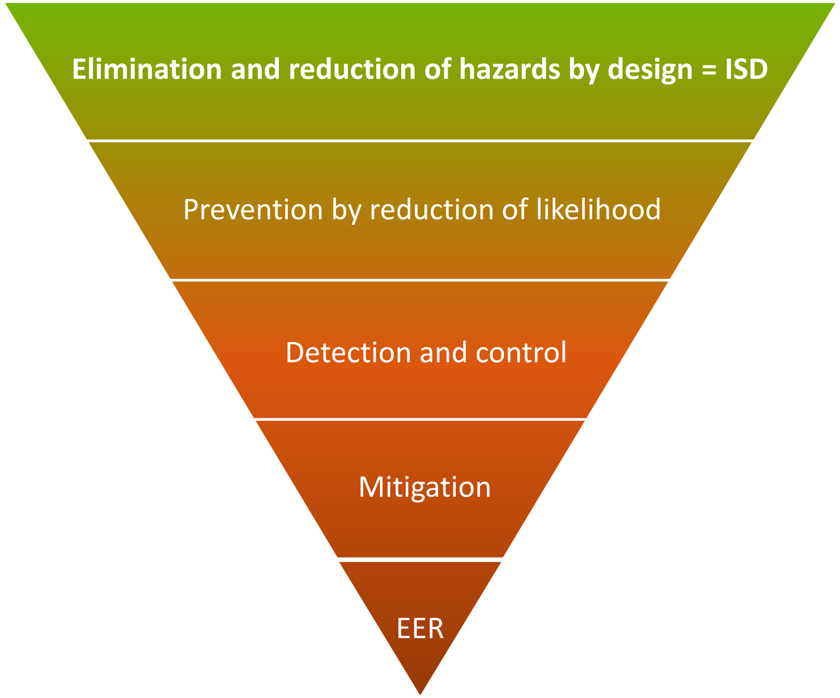
- Increased complexity
- Increased process safety risks
- Reduction of project cycles

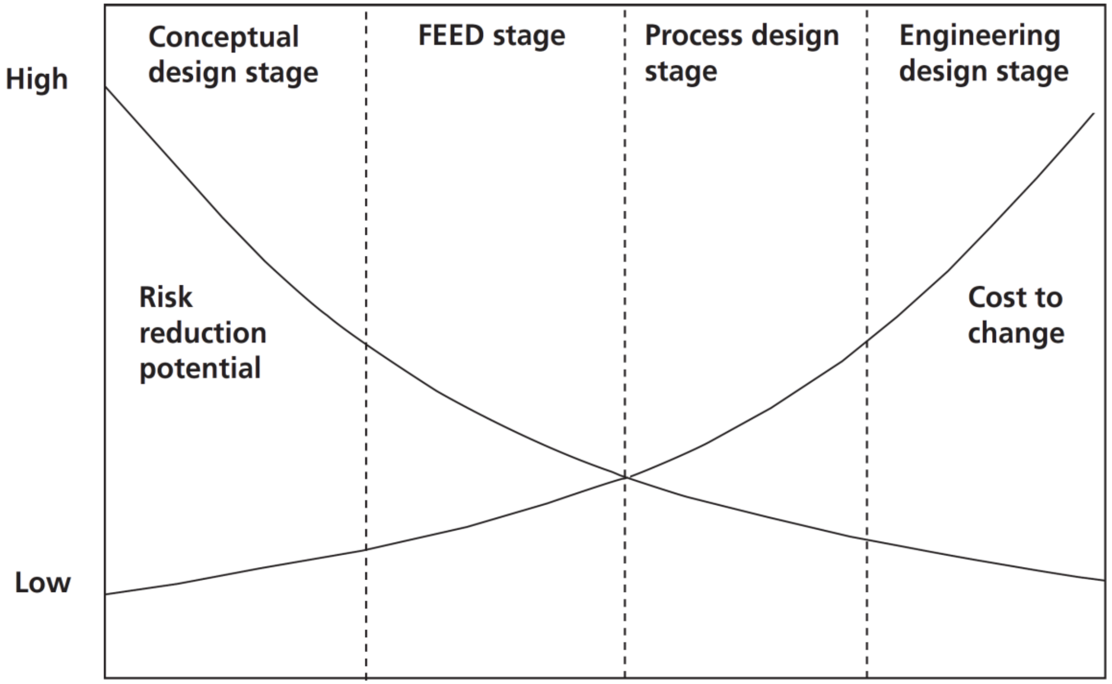
✓ Standardization programs provide opportunity to adopt early in concepts inherently safer design aspects

Inherently Safer Design (ISD) is a fundamental aspect of hazard management with the goal to eliminate or reduce hazards at the source, rather than relying on risk reduction measures

2. ISD approach to hazard management – general considerations

In Hierarchy of Hazard Management principles ISD come first



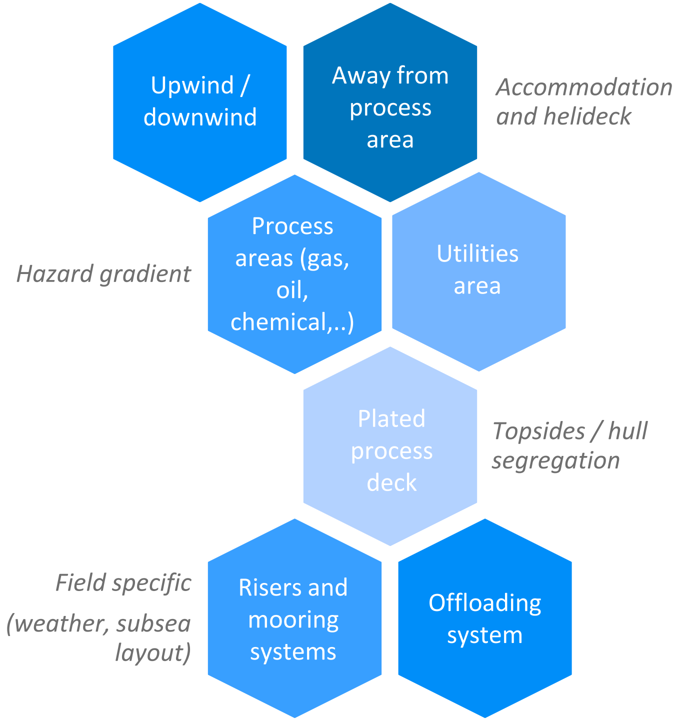


Benefits of ISD early in the design stages - courtesy of Energy Institute

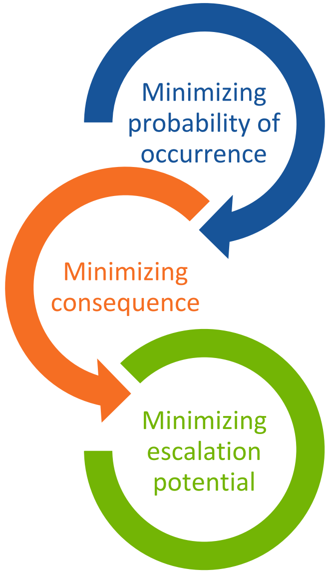
Inherently Safer Design provides the biggest risk reduction level if applied in early stages

2. ISD approach to hazard management – FPSO layout principles

Key features of overall layout



ISD guidelines for equipment layout

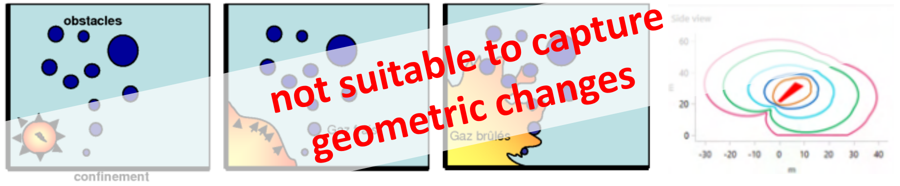


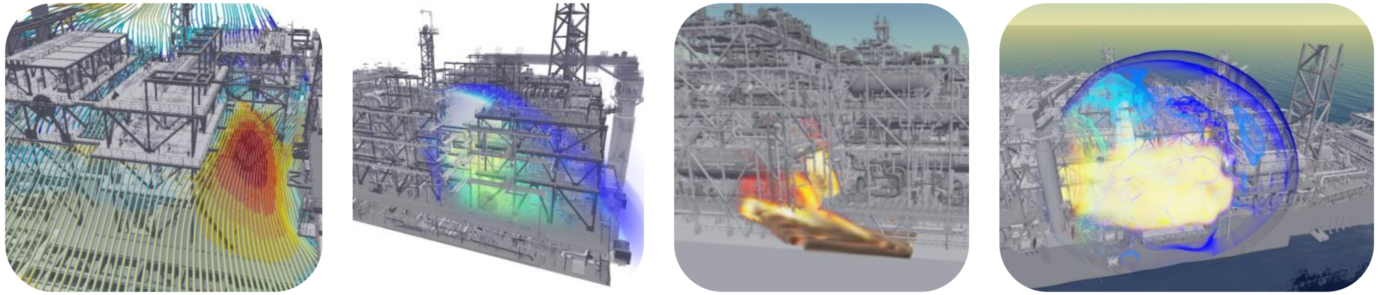
- ✓ *Minimize exposure of ignition sources*
- ✓ *maximize natural ventilation*
- ✓ *maximize explosion venting*
- ✓ *minimize congestion*
- ✓ *minimize confinement*
- ✓ *separate high risk areas from other modules*

Layout of an FPSO is a major ISD feature, with principles to be applied at overall layout and equipment layout level

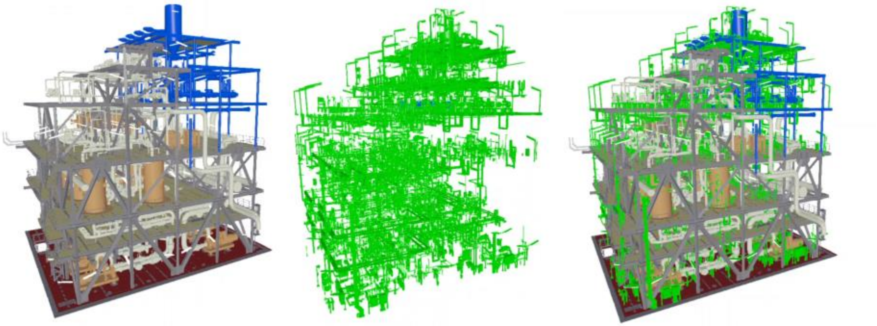
3. CFD-based evaluation of inherently safer layout – 3D databases

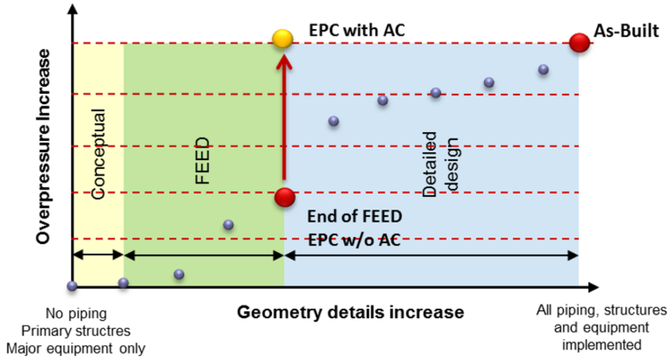
CFD tools for evaluation of geometrical effects on consequence magnitude

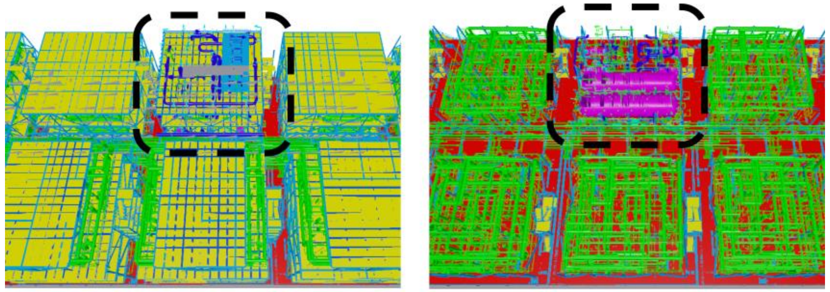




Utilization of 3D databases and Engineer experience to build realistic layouts in early-phases of project





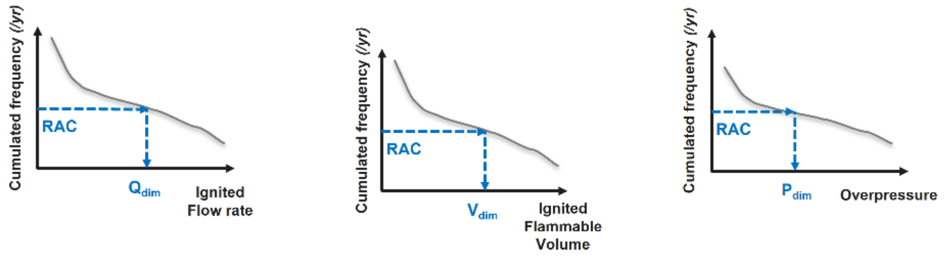


Modeling and layout expertise is required to develop meaningful comparison cases

3. CFD-based evaluation of inherently safer layout – Key parameters

Safety Engineer experience to select representative scenarios

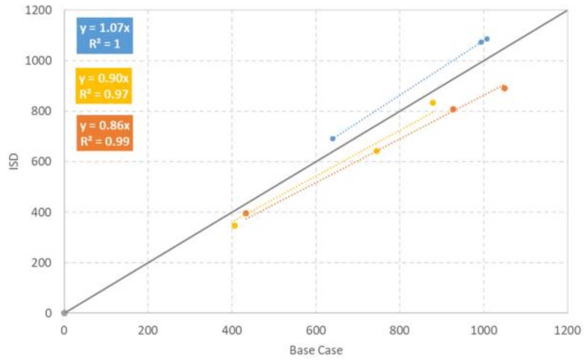
- No process hazard assessment available in early stages
- set of CFD simulation to cover governing scenarios and concept specificities (fluids compositions, process scheme, wind environment)
- deterministic or based on risk drivers from previous projects (DALs)

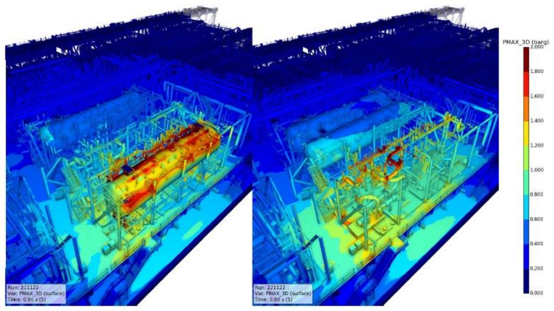


Key performance indicators (KPIs)

- Comparison 1 to 1 between the layout alternatives : base case vs. ISD
- Typical variables studied for each phenomena

Phenomena	Quantitative criteria
Ventilation	ACH : Air Changes Per hour Flow pattern (velocity field) + identification of stagnant areas (flow distribution)
Dispersion	Gas cloud size in module + migration in adjacent module Flammable volume FUEL
Explosion	All : Mean overpressure in areas (incl. Impairment of escape routes) • Structures : Global overpressure on pancake deck • Piping / Structures : mean dynamic pressure (shell/supports) • Equipment : • Local loading : mean overpressure (shell verification) • Global loading : pressure difference (supports verification)
Fire	Flame extents : volume / Length Temperature, Heat flux on target (deck, escape routes, fire water ring main)

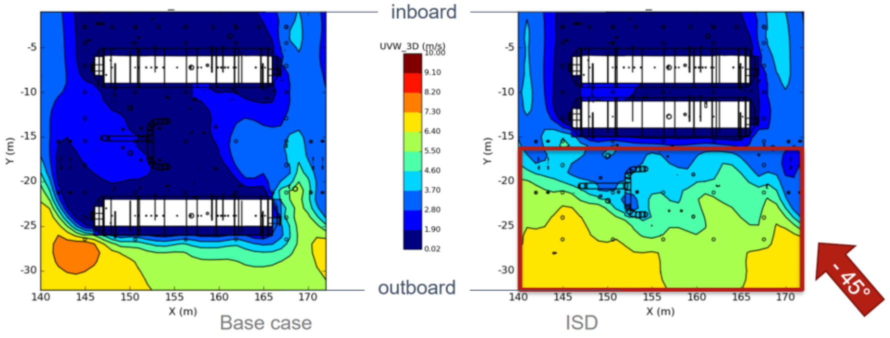


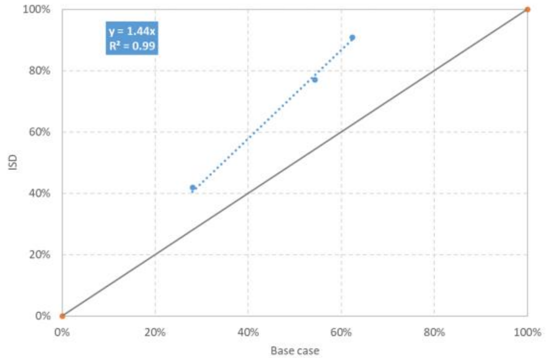


- Quantitative reporting : parity plots, 2D / 3D contour plots,…

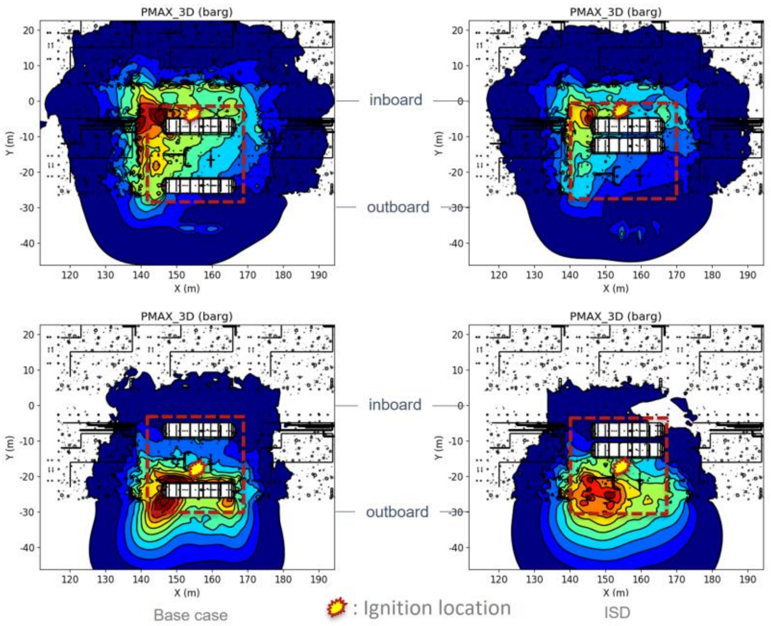
Placing large items near the centerline of the of the facility (inboard)

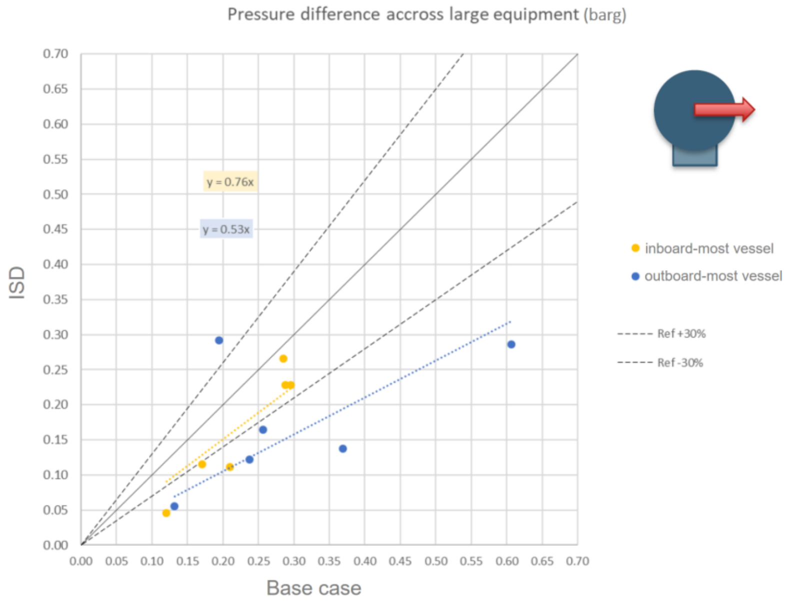
- ✓ promote homogeneous natural ventilation





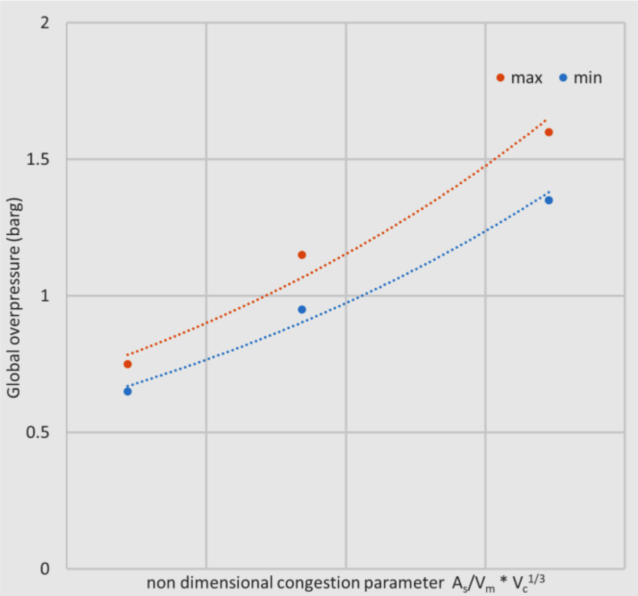
- ✓ maximize explosion venting



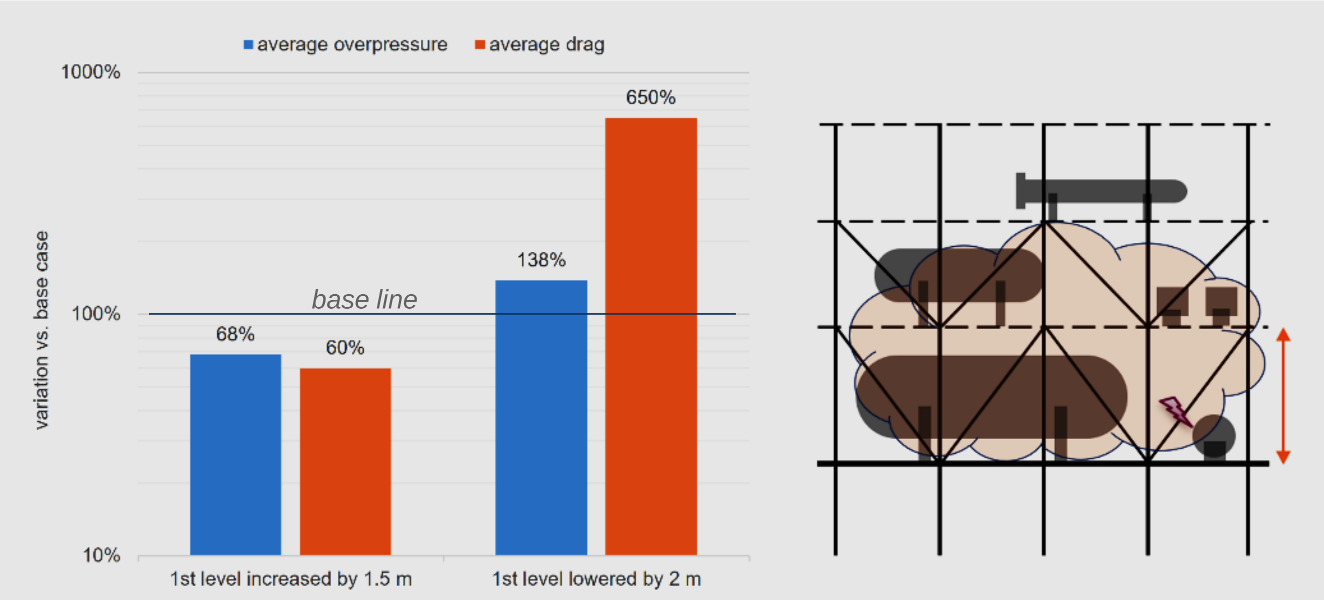


4. Practical applications to FPSO layouts – congestion & confinement

- ✓ **Minimize congestion as far as practicable and identify overly compact layouts**
- ✓ **Minimize confinement by using enough height between floors and maximizing grated floors above process deck**



Effect of congestion density on explosion loads
3 different modules, identical deck space allowed



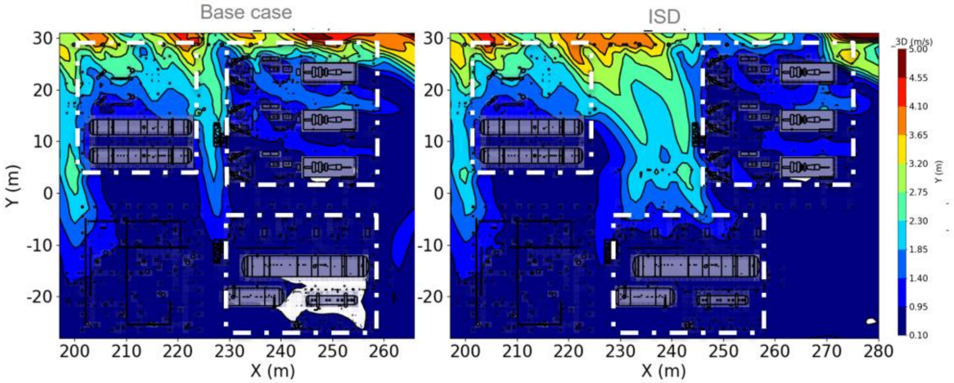
Effect of confinement on explosion loads
Identical modules with 1st level deck height increased / lowered

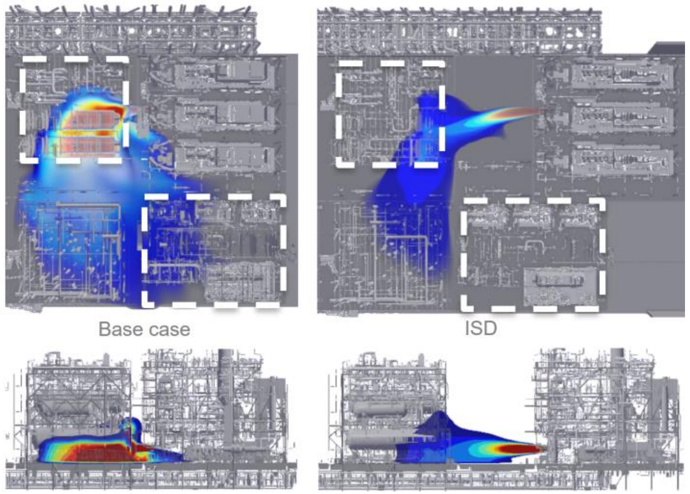
Trade-off between optimized real-estate and potentially un-manageable layout density

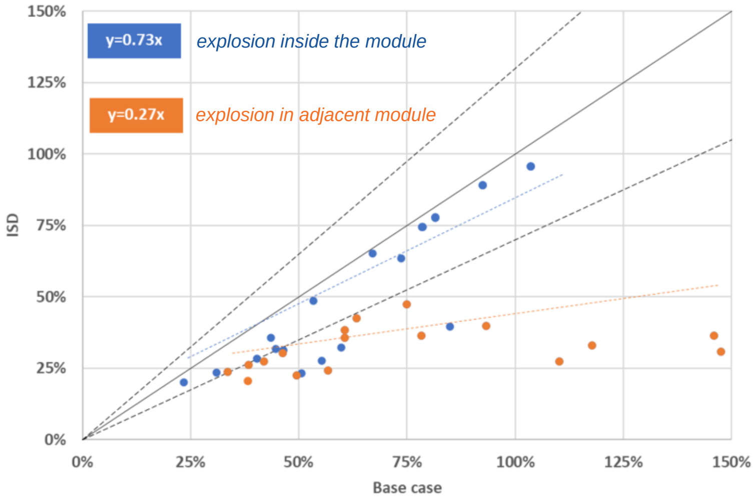
4. Practical applications to FPSO layouts – separation gap

Separation gaps between modules

- ✓ improving ventilation between congested areas, reducing gas cloud size and migration potential
- ✓ segregating high pressure leak sources and strong ignition sources from other areas
- ✓ Improved explosion venting, reduced load on adjacent modules thanks to increased distance, reduced potential for unacceptable consequence
- ✓ Reduced potential for fire escalation







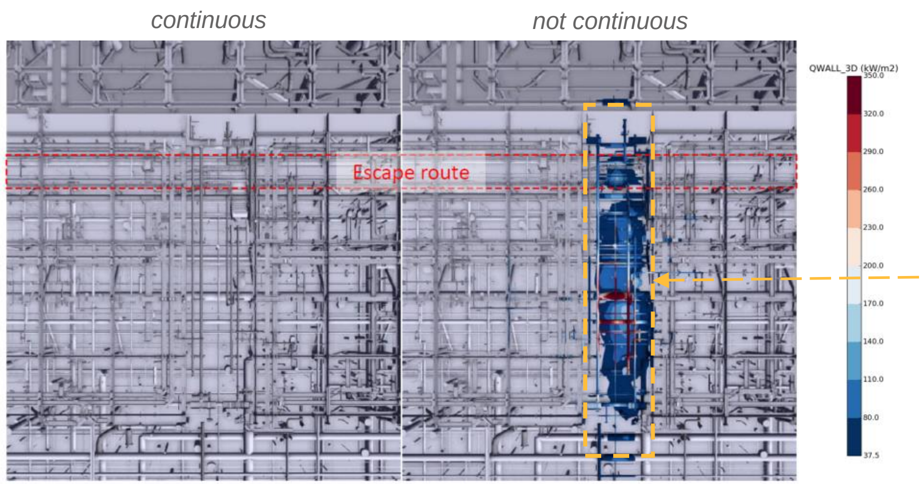
Effect of separation gap on explosion loads

Separation gaps affords strong safety benefit albeit requires additional (empty) topside footprint

4. Practical applications to FPSO layouts – continuous process deck

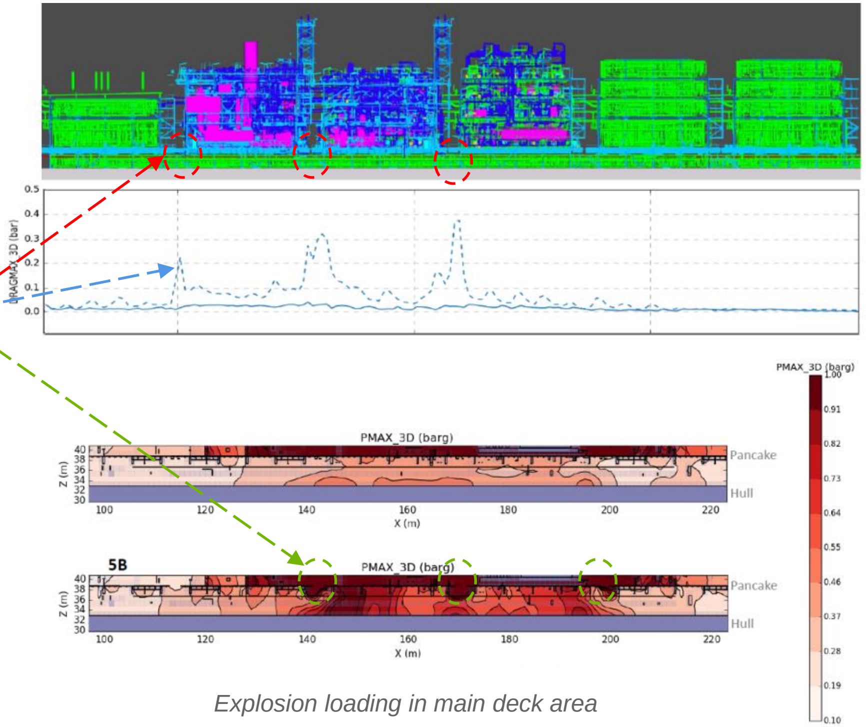
Closing the gap between topside modules plated process decks

- ✓ Reduce fire/explosion loading of main deck from topside events
- ✓ Reduce impairment of escape routes on main deck from topside events



Fire exposure of main deck from topside jet fire

No solid deck in between modules



Explosion loading in main deck area

Fully continuous plated process deck improves topsides / hull segregation albeit a more complex integration

4. Practical applications to FPSO layouts – overall layout

Base case with very large gas throughput

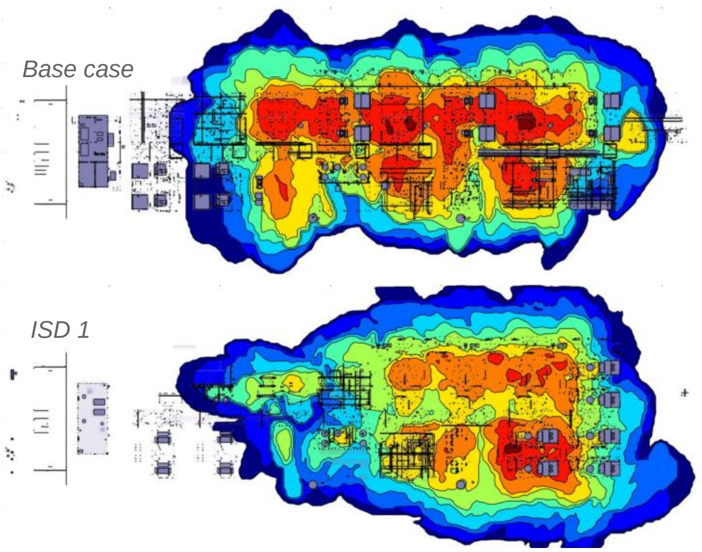
- High gas to oil ratio, very large gas plant, focus on minimizing HP inventories
- ➢ initial probabilistic safety assessment concluded intolerable explosion risk
- ➢ high contribution from strong ignition sources (gas turbines in process area)

Inherently Safer Design step 1

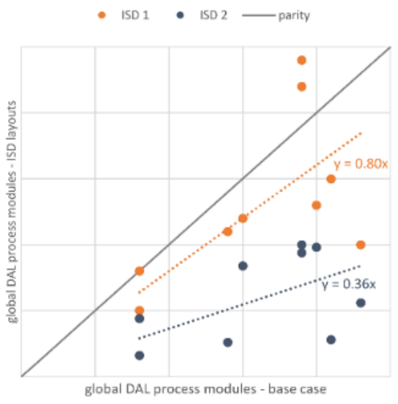
- Re-shuffle layout intra and inter modules, no process change
- ➢ overall risk reduction by 20%, still challenges in high risk areas

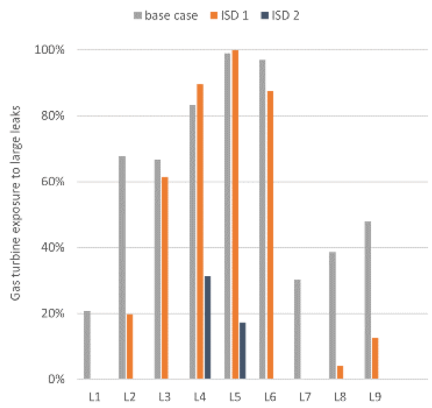
Inherently Safer Design step 2

- Change of concept reducing throughput by 33%
- Saved deck space used as separation gap for high risk areas
- ✓ Less process equipment → less leak sources (simplification)
- ✓ Less congested footprint → less gas accumulation, enhanced ventilation and explosion venting (attenuation)
- ✓ Less exposure of main ignition sources to process leaks (segregation)
- ➢ Explosion loads reduced to 1/3 of base case



Flammable gas presence likelihood





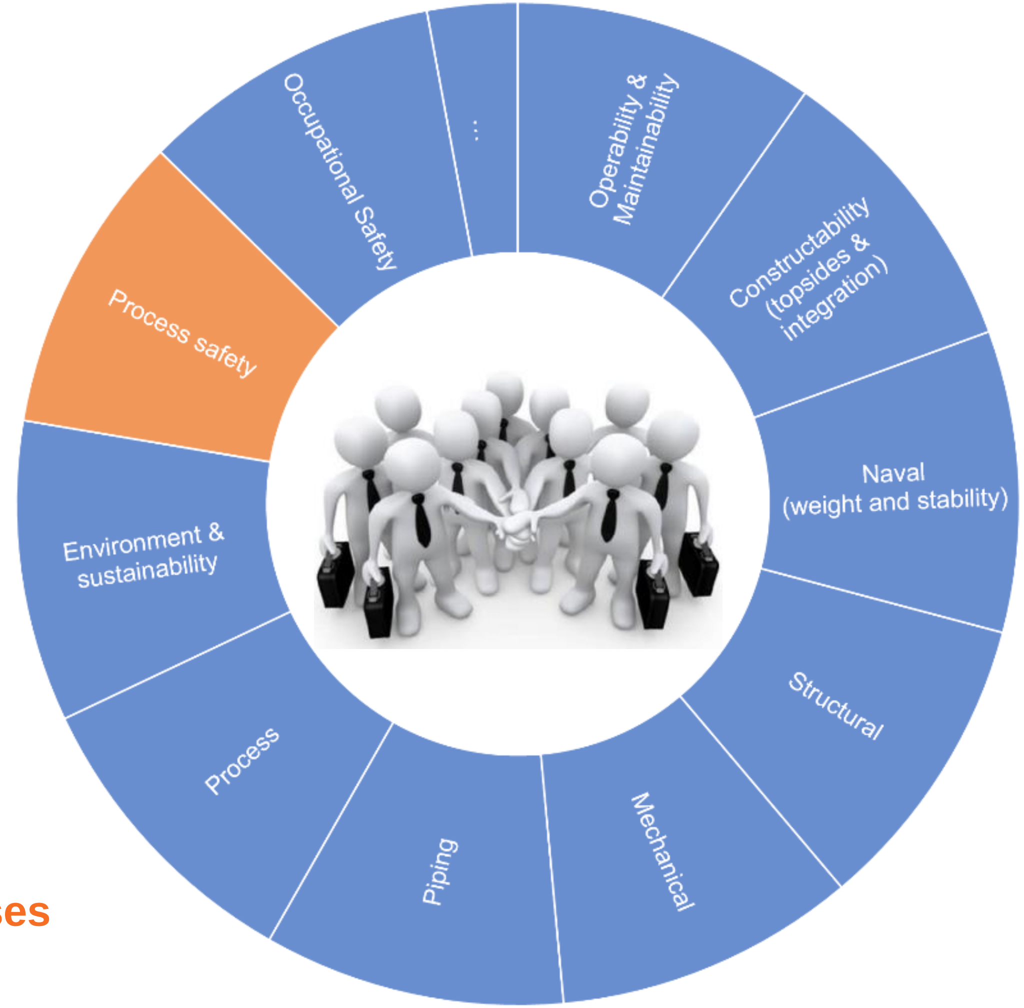
Adequately applied ISD principles yield significant process safety improvements

5. Inherently Safer Design evaluation to support decision making

SBM OFFSHORE

Decision making process

- ✓ Safety improvements are quantified
- ✓ Process safety is an important aspect but not the only driver
- ✓ Trade-off between improvement cost and risk reduction benefits
- ✓ A multi-disciplines approach is required to evaluate impacts (CAPEX but not only)
- ✓ Additional ISD options may be identified during the decision-making process as a result of the multi-discipline approach



Documentation of risk related decision making in early phases provide a solid basis for the demonstration of ALARP

6. Conclusions

CFD-based evaluation of inherently safer FPSO layouts

- ✓ Application of ISD principles during layout development is a fundamental process safety activity
- ✓ With the combination of engineering experience and advanced tools, options can be objectively compared within a reasonable time-frame
- ✓ Identify key risk drivers, pain points for design, no-gos

Supporting decision making process

- ✓ There is no definitive layout or "one that fits all" approach
- ✓ Need stakeholders to compromise between design options (Process safety risks, CAPEX, Execution risks, Operability, Sustainability,…)
- ✓ Agile approach successfully implemented on recent fast-track project, confirmed by detailed probabilistic studies

More applications

- ➢ Embed findings in standardization practices → from one-off case studies to good layout practices, systematic ISD evaluations
- ➢ Evaluation of new concepts, new technologies
- ➢ Methodology applicable to any modularized / congested plant (offshore, onshore, oil & gas processing, LNG, H2, NH3…)

CFD-based evaluation of inherently safer FPSO layouts

Etienne Guinot – Safety & Loss Prevention Lead Engineer – etienne.guinot@sbmoffshore.com
Laurent Paris – Explosion Safety Technical Manager – laurent.paris@efectis.com
Josue Quilliou – Principal Engineer – josue.Quilliou@gexcon.com