

Introduction to Modular Safety Concepts

Introduction to VDI Standard 2776 Part 3

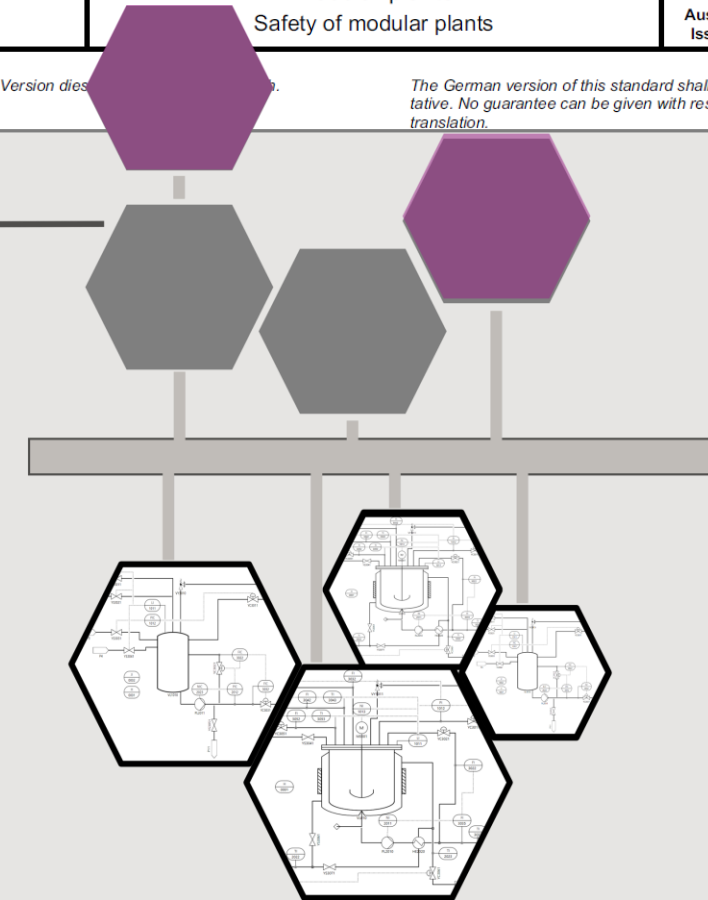
2nd – 3rd December 2024

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and Dresden University of Technology

Dr. Frank Stenger, Dr. Christian Bramsiepe,
Margit Hahn / Evonik Operations GmbH

ICS 71.020	VDI-RICHTLINIEN	Januar 2024 January 2024
VEREIN DEUTSCHER INGENIEURE	Verfahrenstechnische Anlagen Modulare Anlagen Sicherheit modularer Anlagen Process engineering plants Modular plants Safety of modular plants	VDI 2776 Blatt 3 / Blatt 3 Ausg. deutsch/englisch Issue German/English
<i>Die deutsche Version dieses Standards ist die verbindliche Referenzversion.</i>		<i>The German version of this standard shall be taken as authoritative. No guarantee can be given with respect to the English translation.</i>

Modular
Infrastructure



Agenda

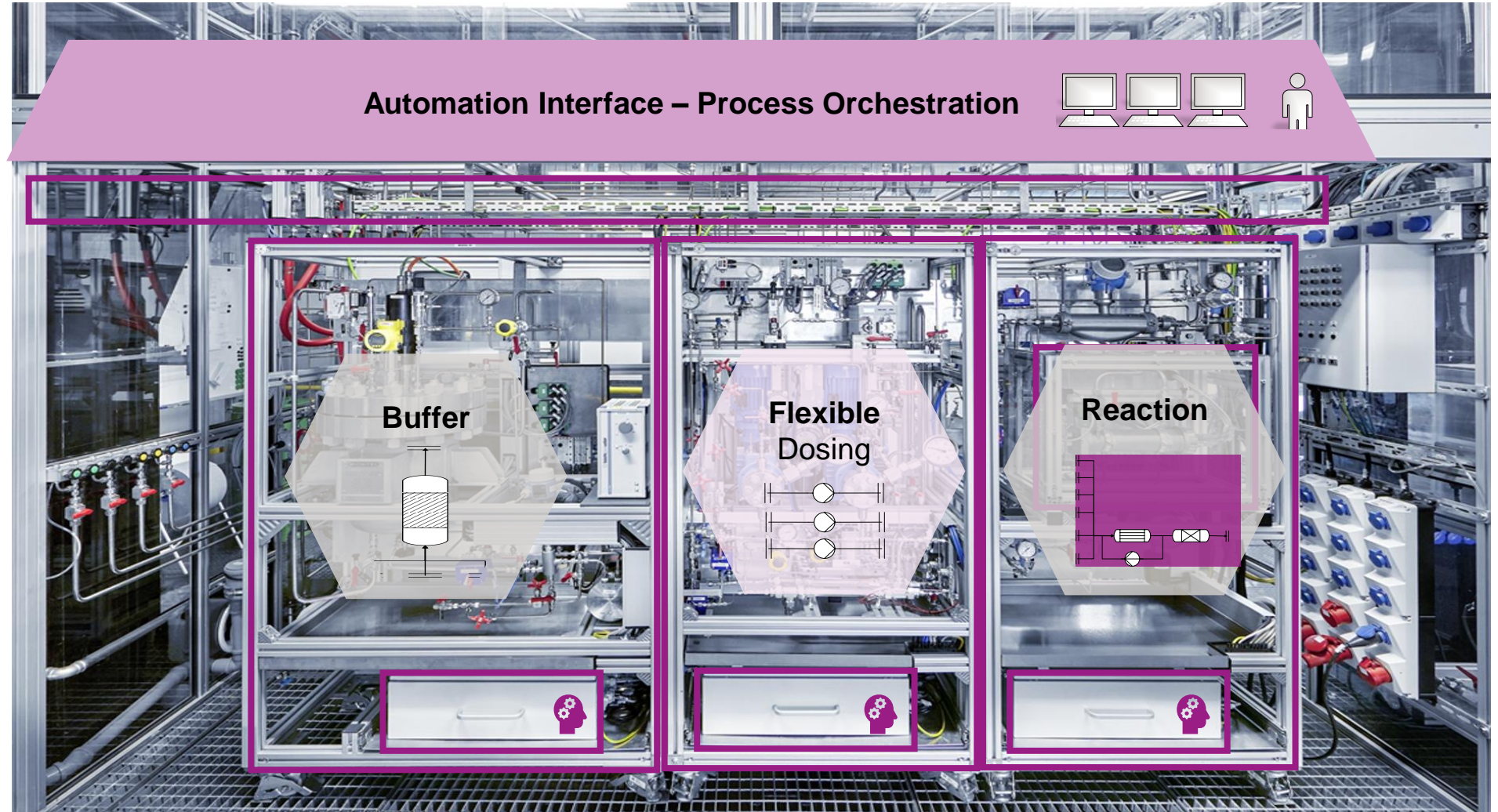
- 1. Introduction Modular Plants & VDI Standard 2776**
- 2. Modular Safety Concepts & Safety Studies (HAZOP) for Modular Plants**
- 3. Ideas on Use Cases for
Modular Safety Concepts & Safety Studies (HAZOP) for Monolithic Plants**
- 4. Summary and Discussion**

Key developments

The Modular Plants Technology platform developed key design principles & new technology solutions

Design principles & tech solutions

- Functional process design
- Decentralized intelligence
- Standardized data & control interfaces
- Lean Process Orchestration layer
- Appropriate infrastructure

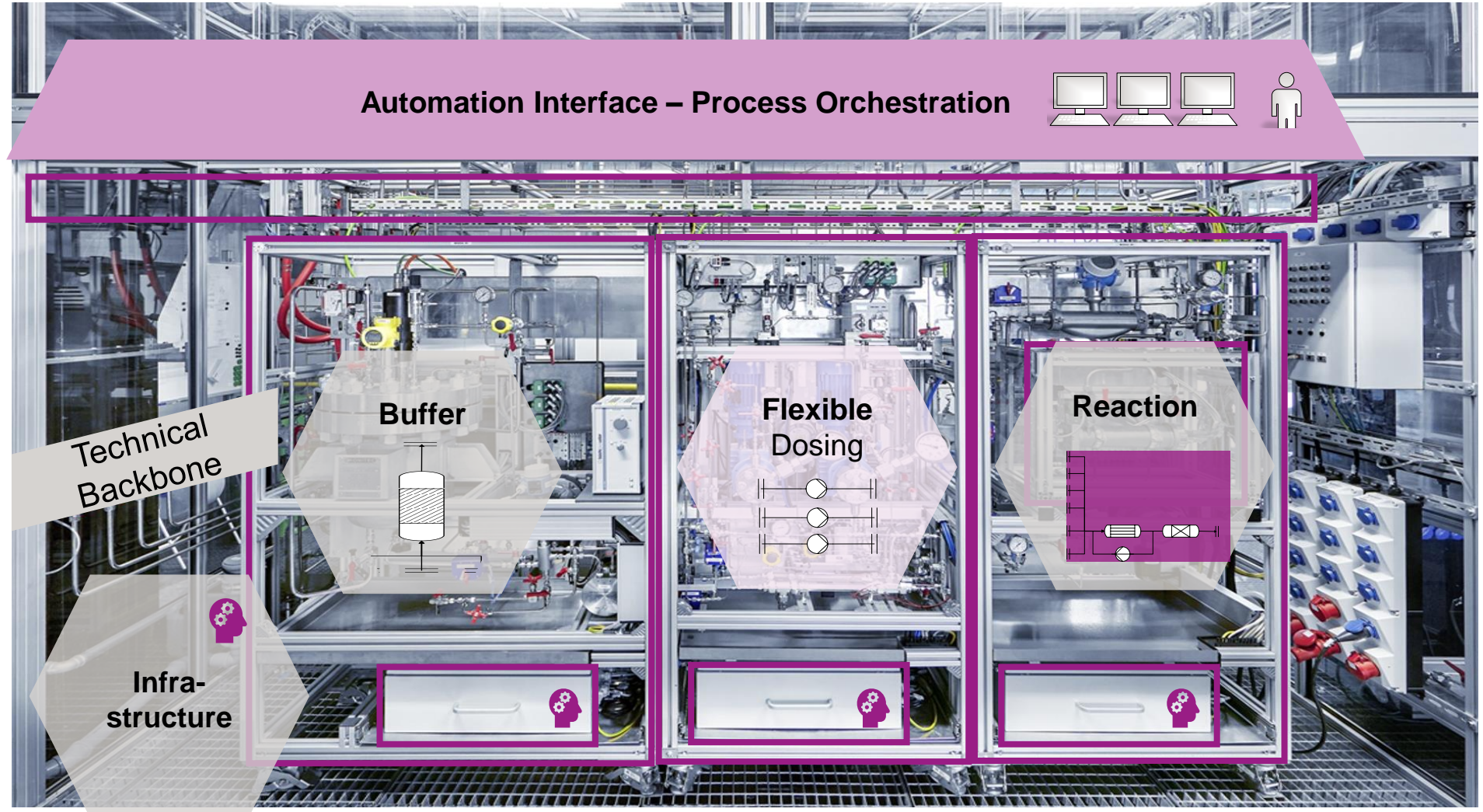


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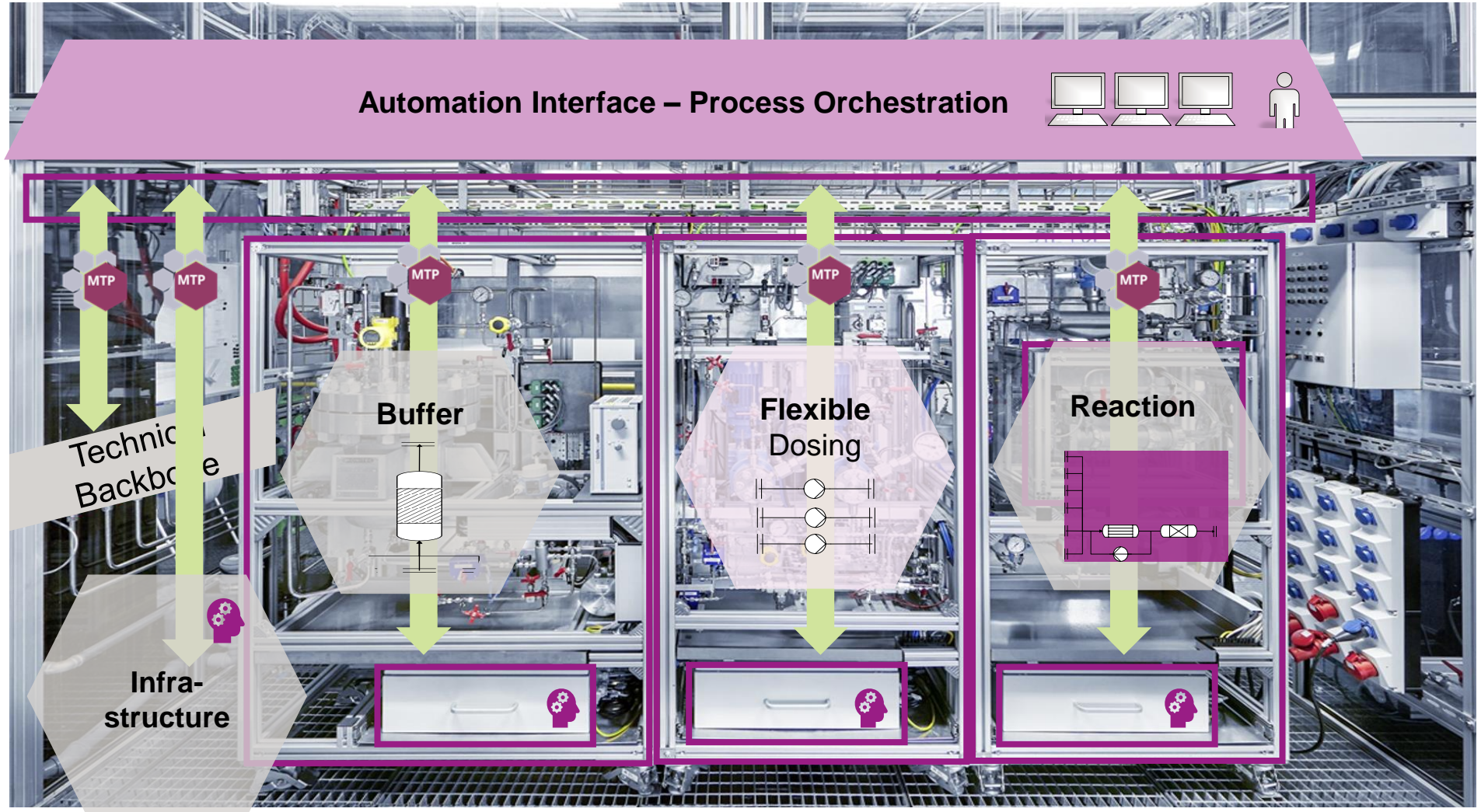


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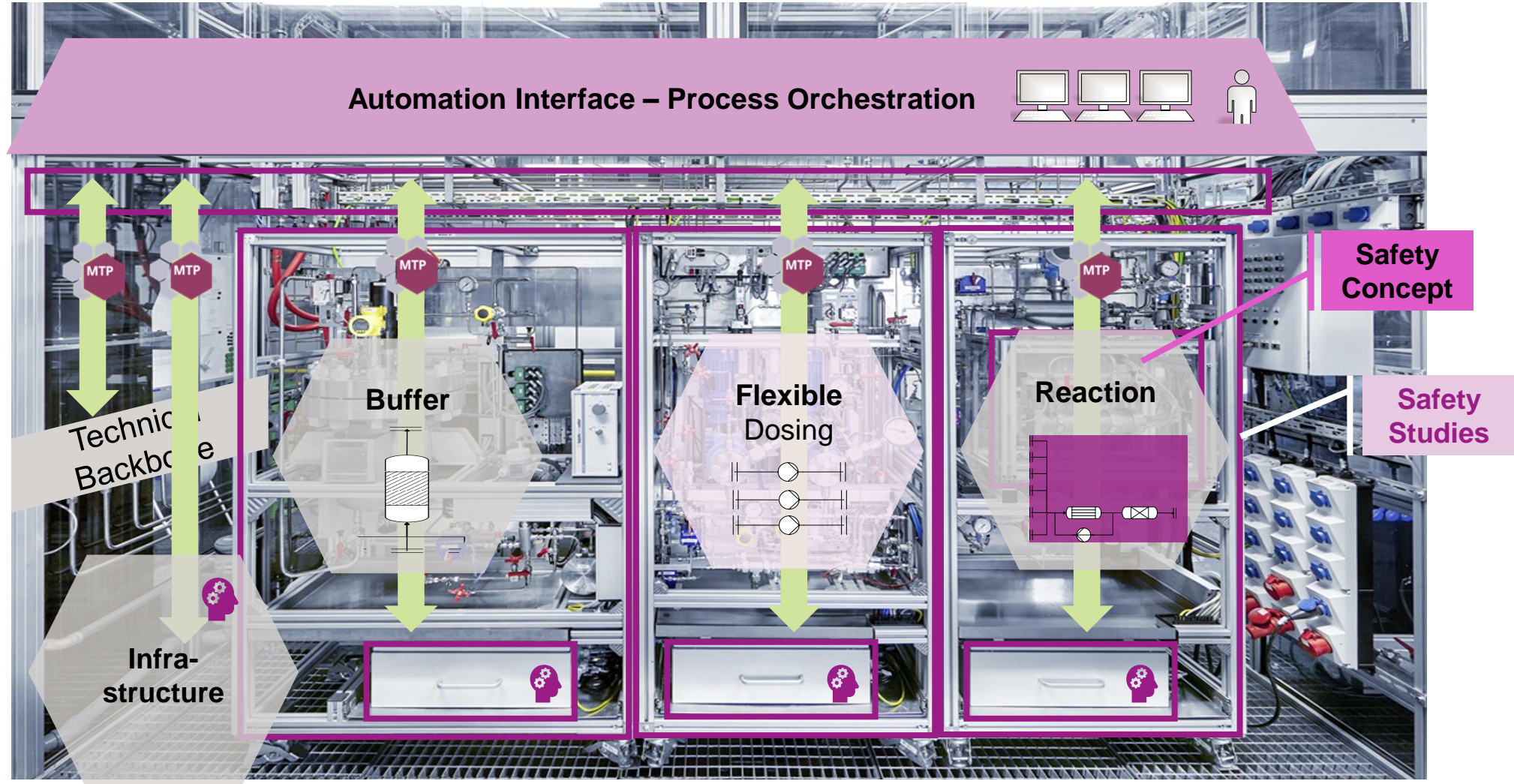


Key developments

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Design principles & tech solutions

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State of the Art is summarized in the VDI Standard „Modular Plants“ with focus here on Part 3 „Safety of Modular Plants“

VDI Standard 2776:

- Standards give overview of process engineering planning principle and major roles
- Part 1 – Fundamentals and definitions
- Part 2 – Planning and design of modular Plants
- **Part 3 – Safety of modular plants**

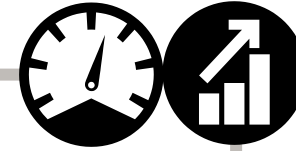
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5 Safety-related and safety-conceptual characteristics of modular plants 11					
5.1 Fundamental differences and plant safety		6 Safety concept and safety measures of modular plants 18			
5.2 Autarky of the safety concept		6.1 Classification of intra- and intermodular risks and risks for the overall system			
5.3 Importance of the safety concept		6.2 Intramodular safety measures for intended use			
5.4 Allocation of roles in plant safety		6.3 Intermodular safety measures			
		6.4 Organizational considerations			
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		7.1 Implementation of hazard and risk analysis 34			
		7.2 Methods for hazard and risk assessment 35			
		7.3 Changes to the elements of the modular concept (management of change)..... 39			

→ Modular plants need a change in roles during the engineering lifecycle

→ Modular plants can accelerate timelines

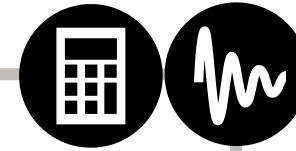
Modularization: Value proposition

FASTER
TIME-TO-MARKET



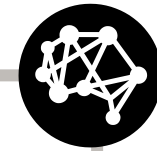
- 50%

REDUCED
ENGINEERING EFFORT

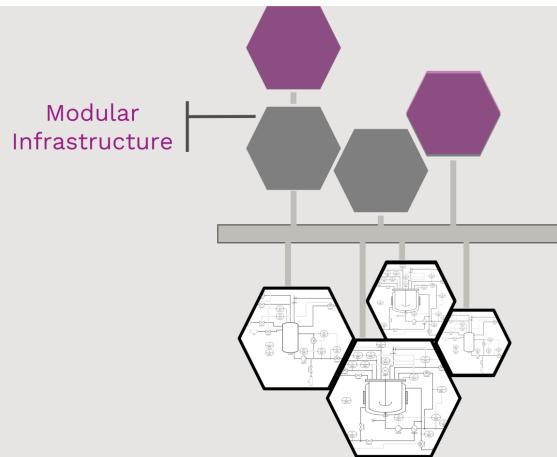


- 70%

INCREASED FLEXIBILITY

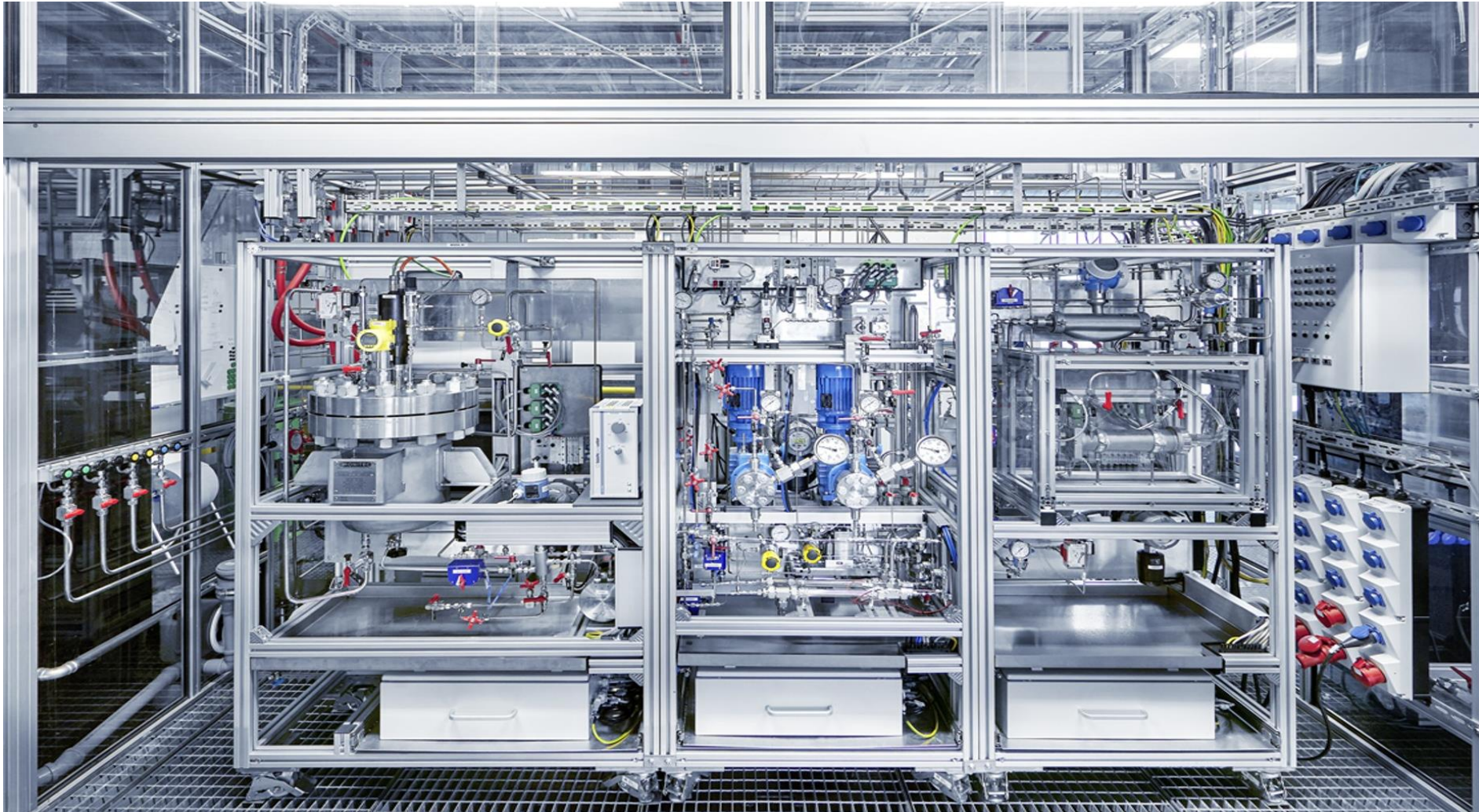


+ 80%

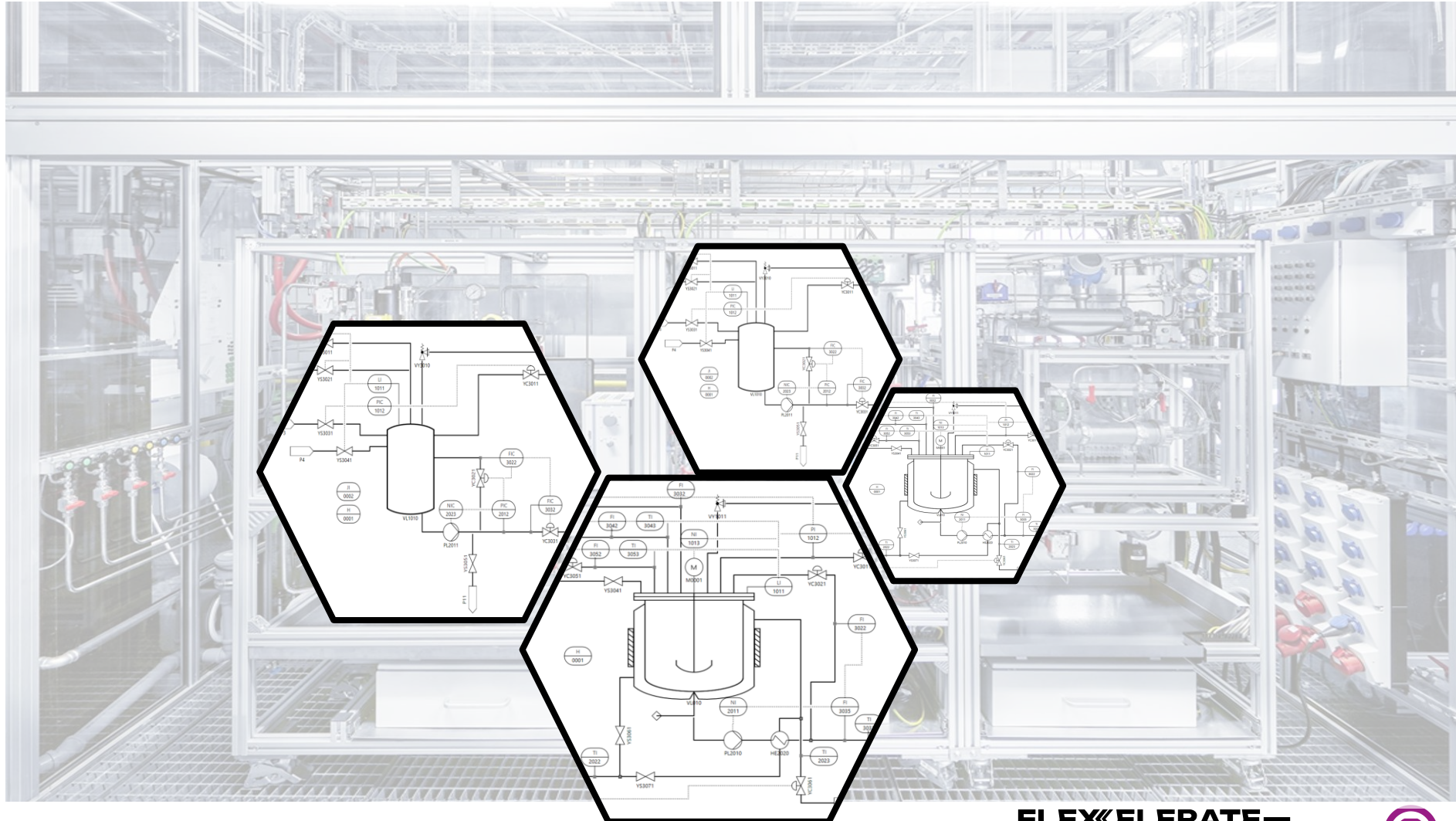


ZVEI, NAMUR 2020

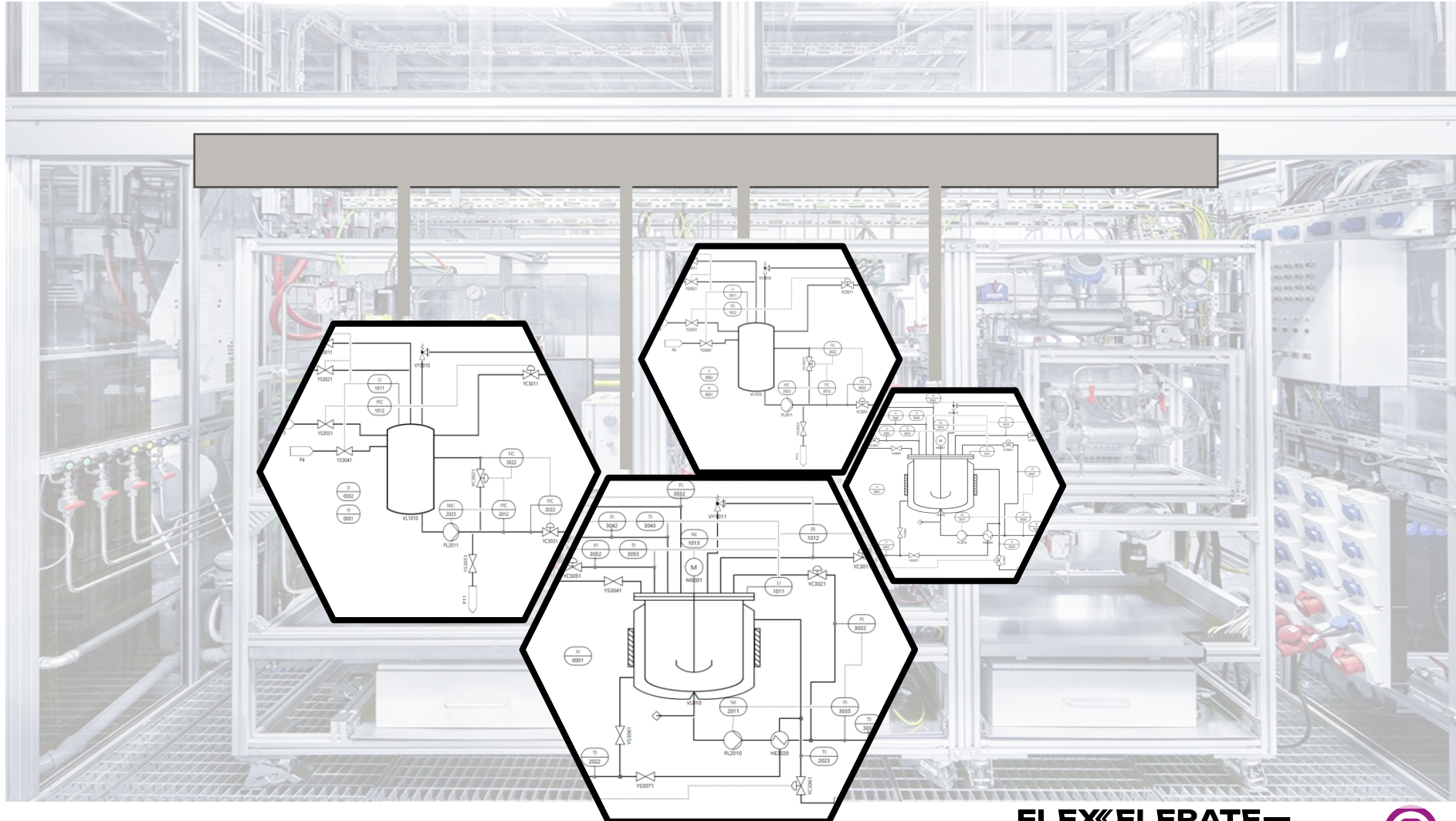
Modular Plants follow a hierarchical structure for process equipment and automation



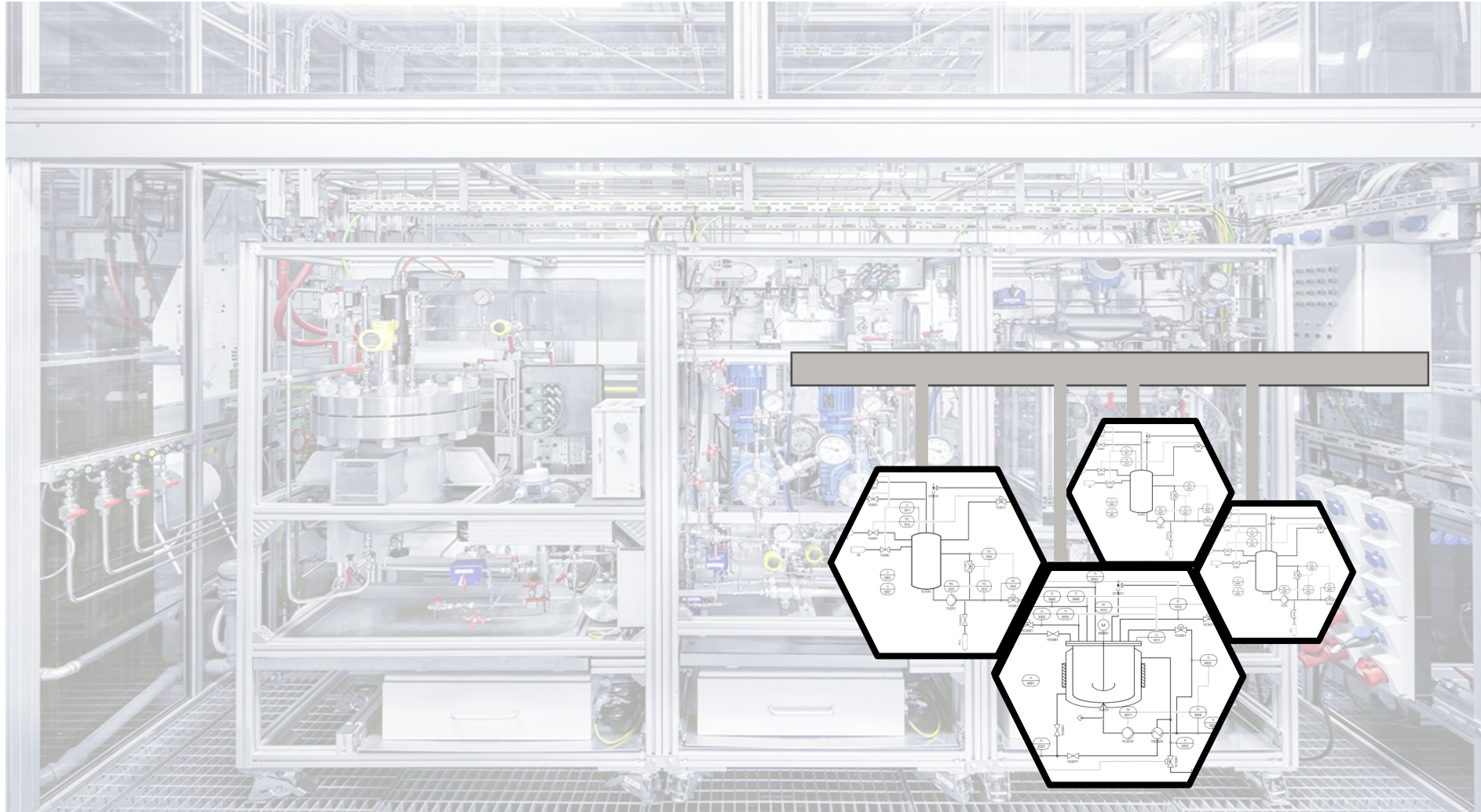
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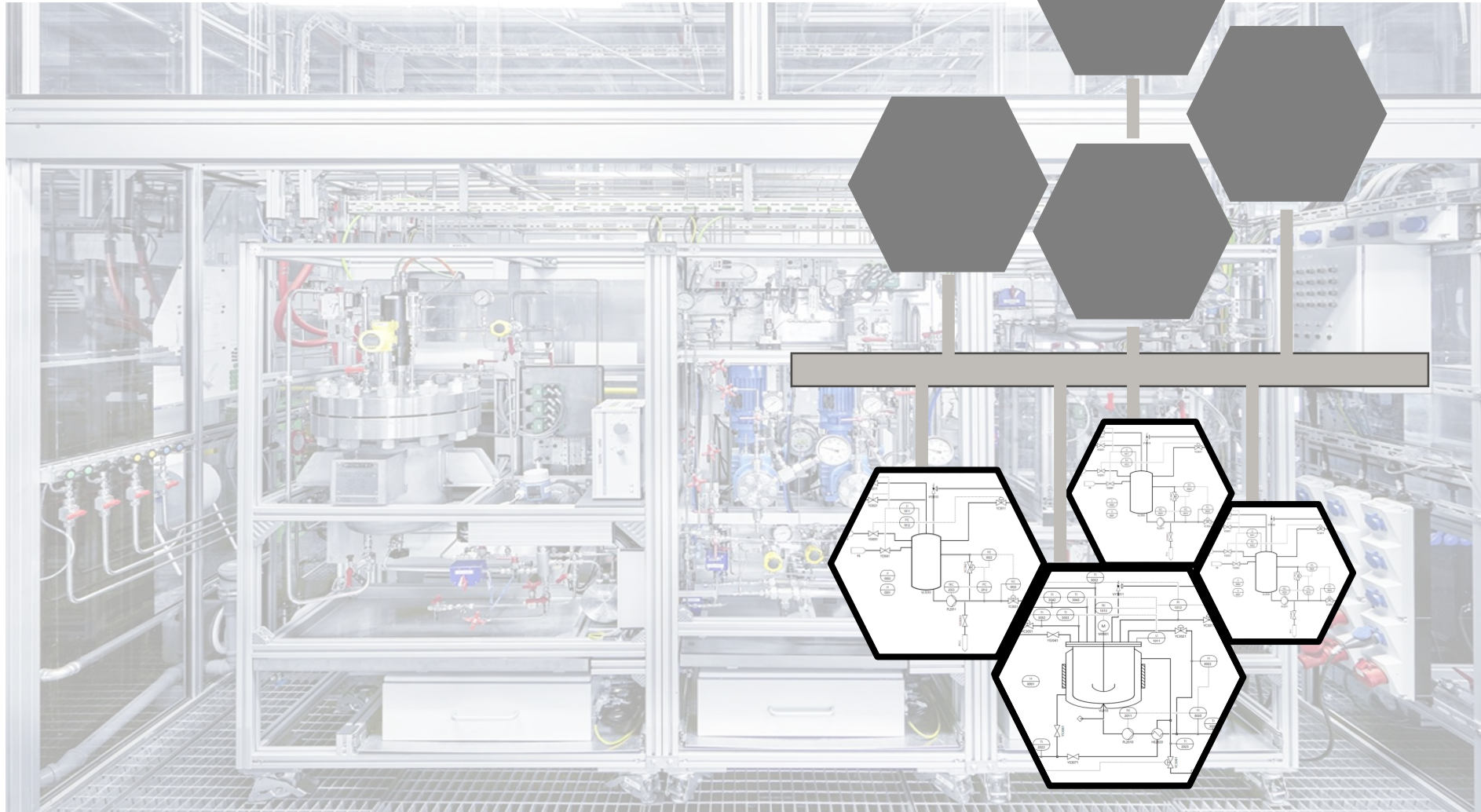
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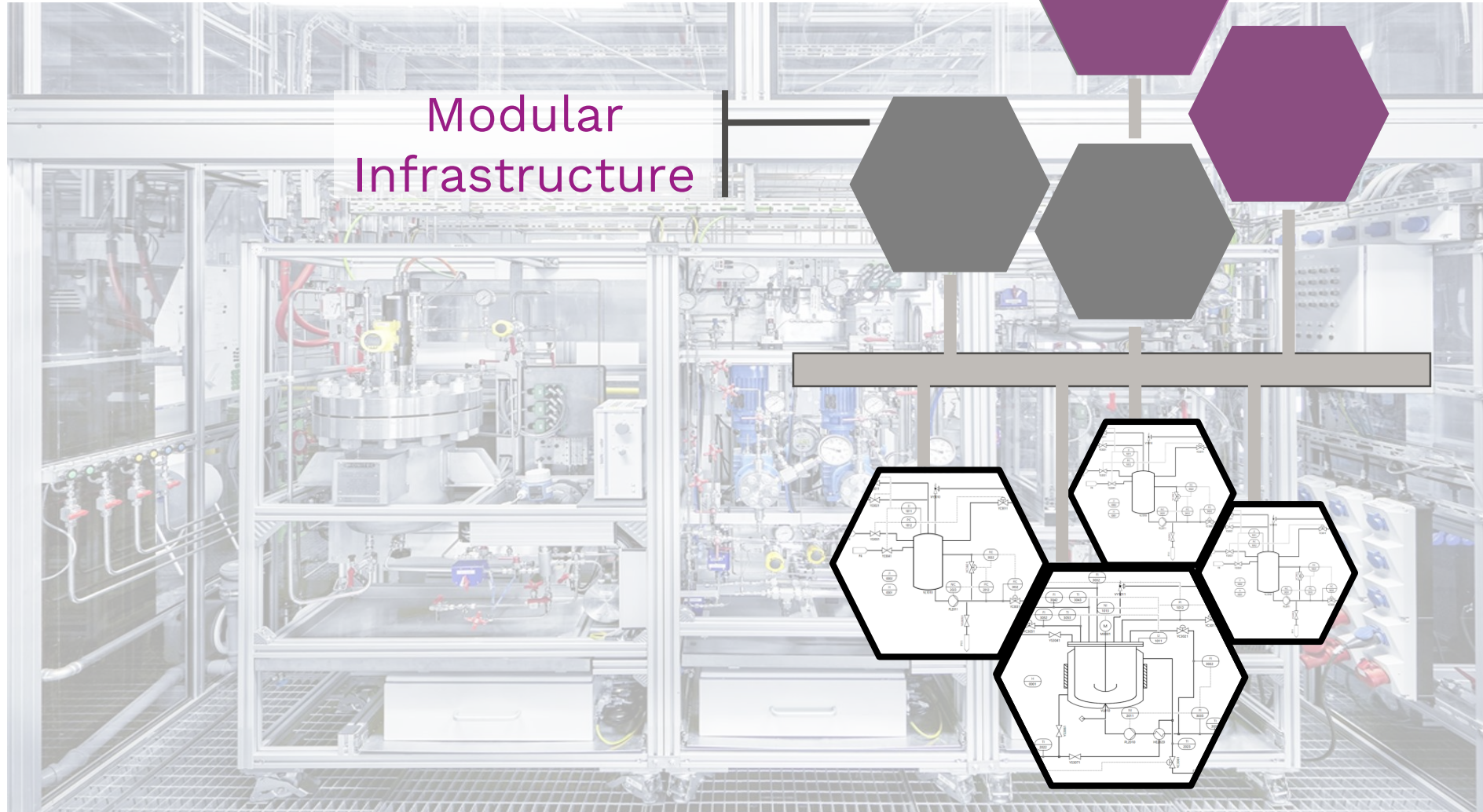
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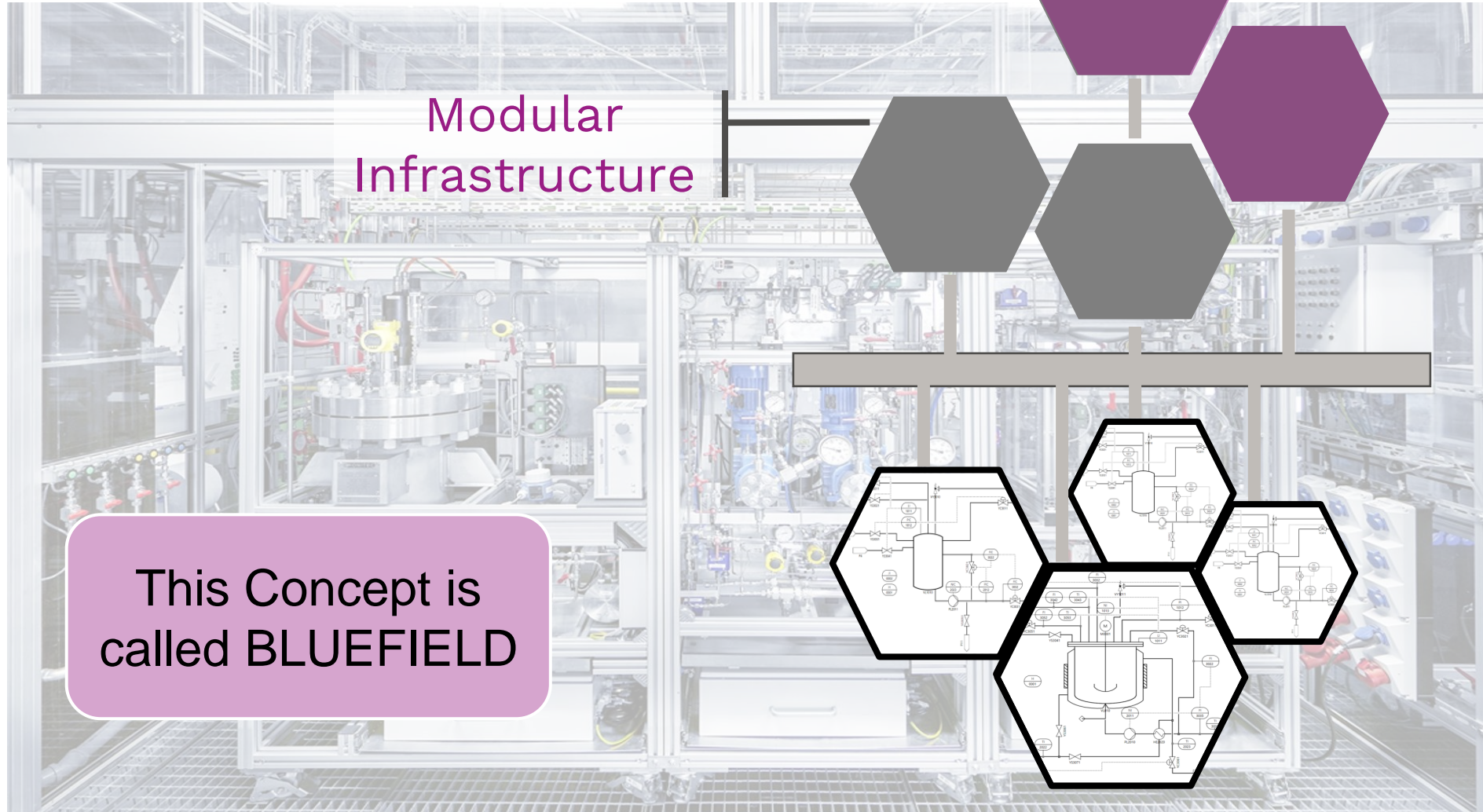
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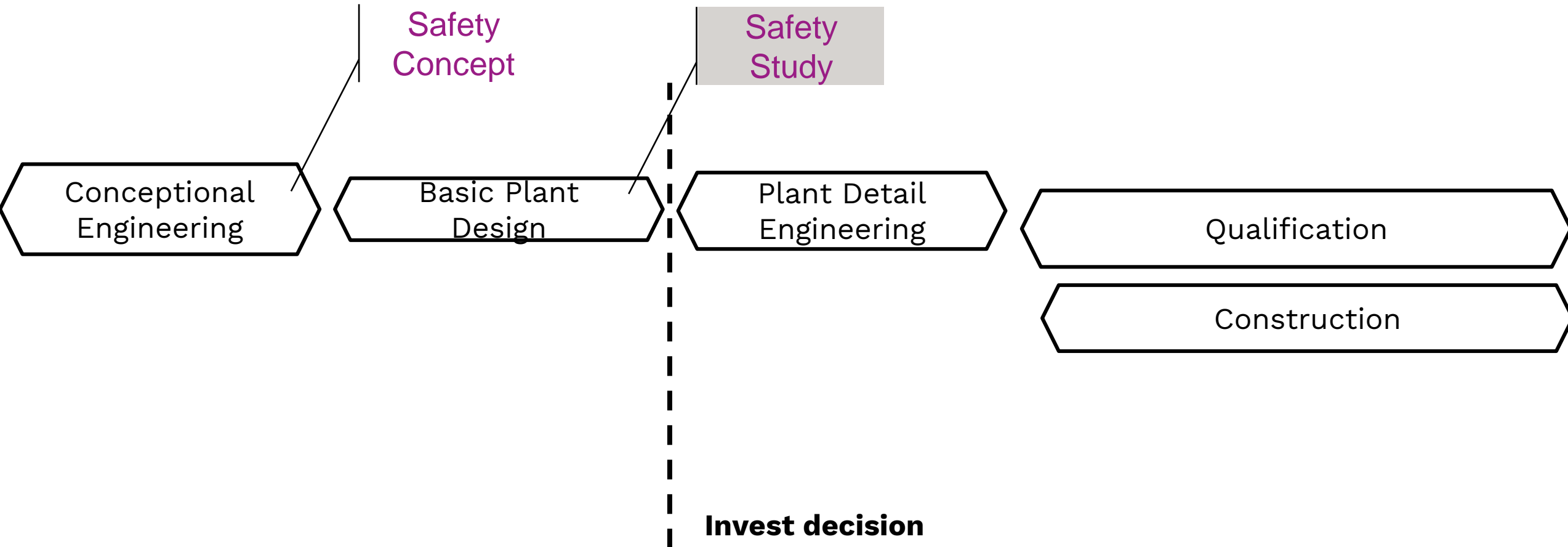
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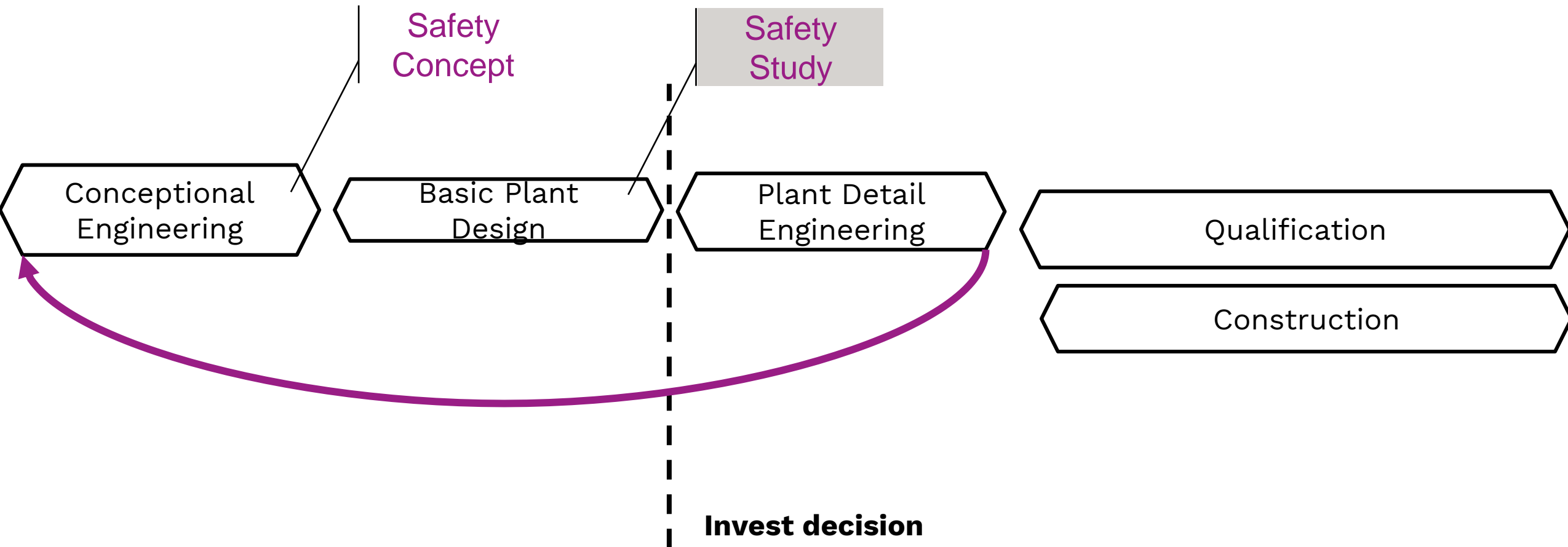
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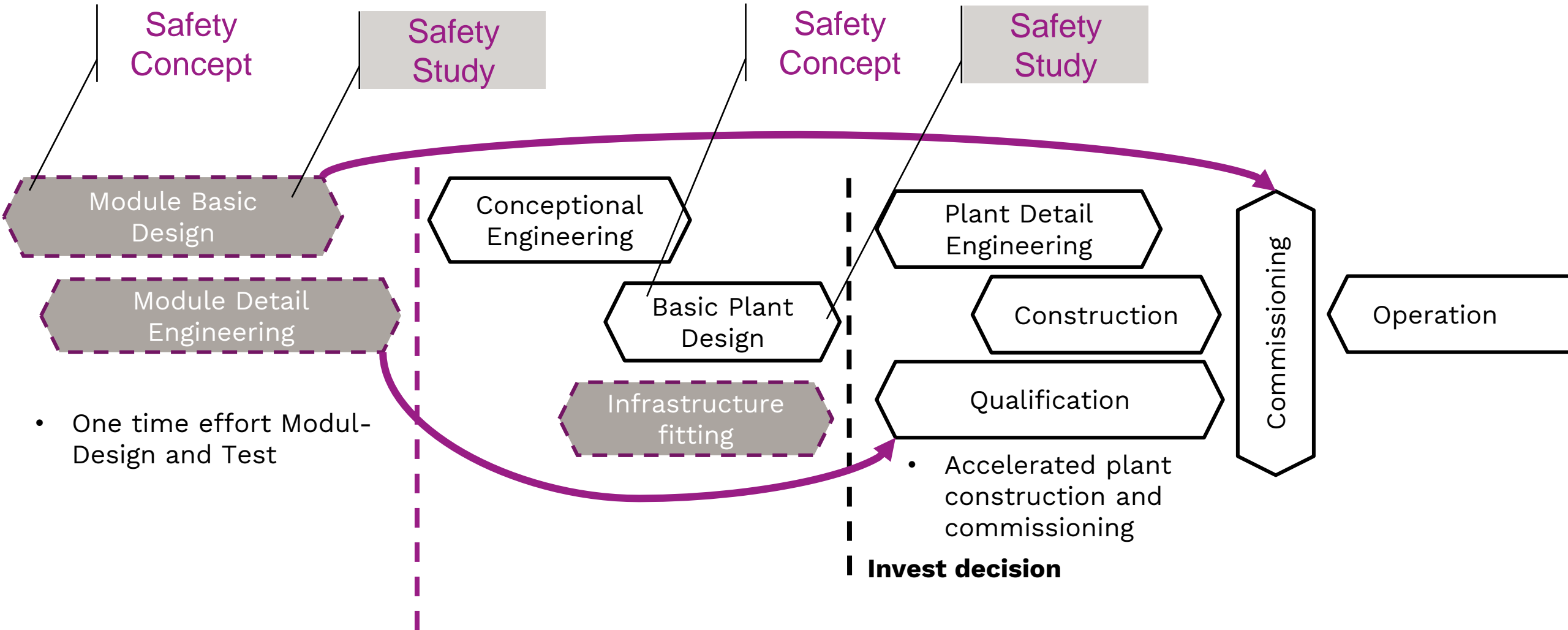
Classic engineering follows a line, modular engineering works in different roles, independently



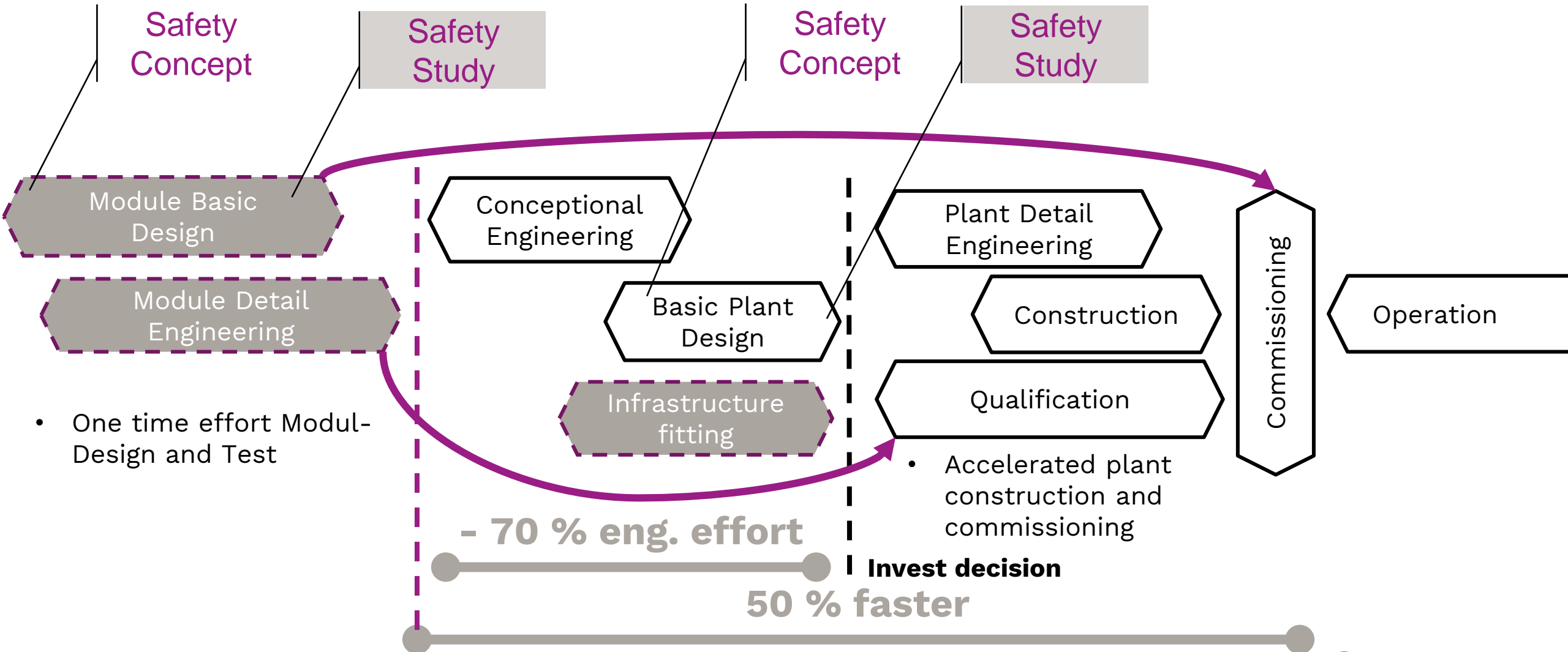
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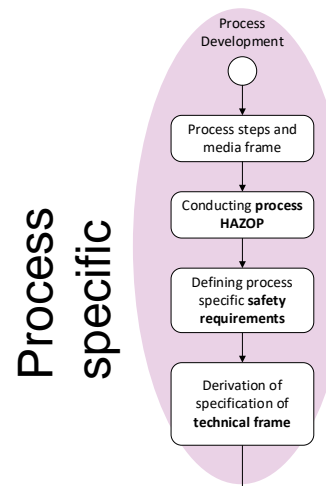
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The key roles and tasks in modularization – enabling fast, changeable and flexible solutions

END USERS

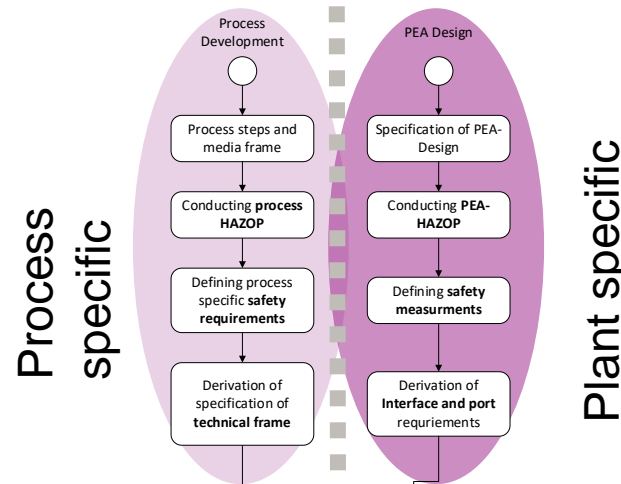
- Designs process
- Defining safety concept for process
- Selects modules to fit process
- Checks overall safety concept and safety studies



The key roles and tasks in modularization – enabling fast, changeable and flexible solutions

END USERS

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MANUFACTURERS

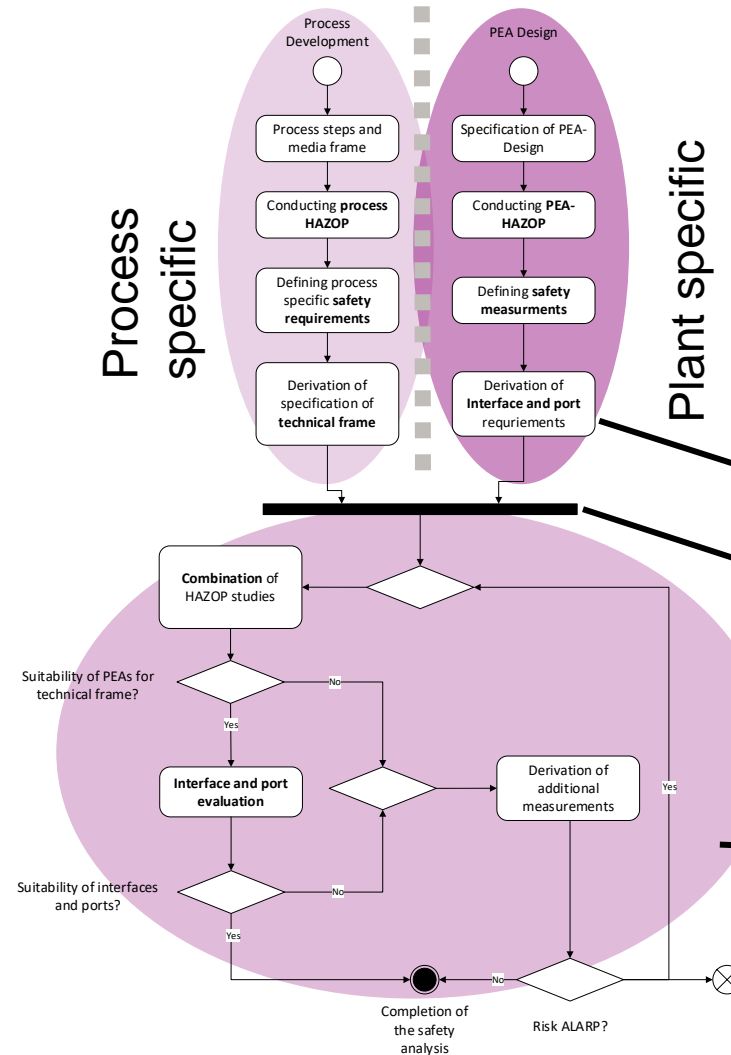
- Modularizes its plant design
- Provides single or multiple modules
- Defining safety concept and safety study for modules

The key roles and tasks in modularization – enabling fast, changeable and flexible solutions

END USERS

- Designs process
- Defining safety concept for process
- Selects modules to fit process
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Prepared Safety concepts can be built on.
Mapping of Safety requirements and capabilities



MANUFACTURERS

- Modularizes its plant design
- Provides single or multiple modules
- Defining safety concept and safety study for modules

Fast

Changeable

Flexible

Prepare safety analysis in modular process plant

- **Holistic view on safety**

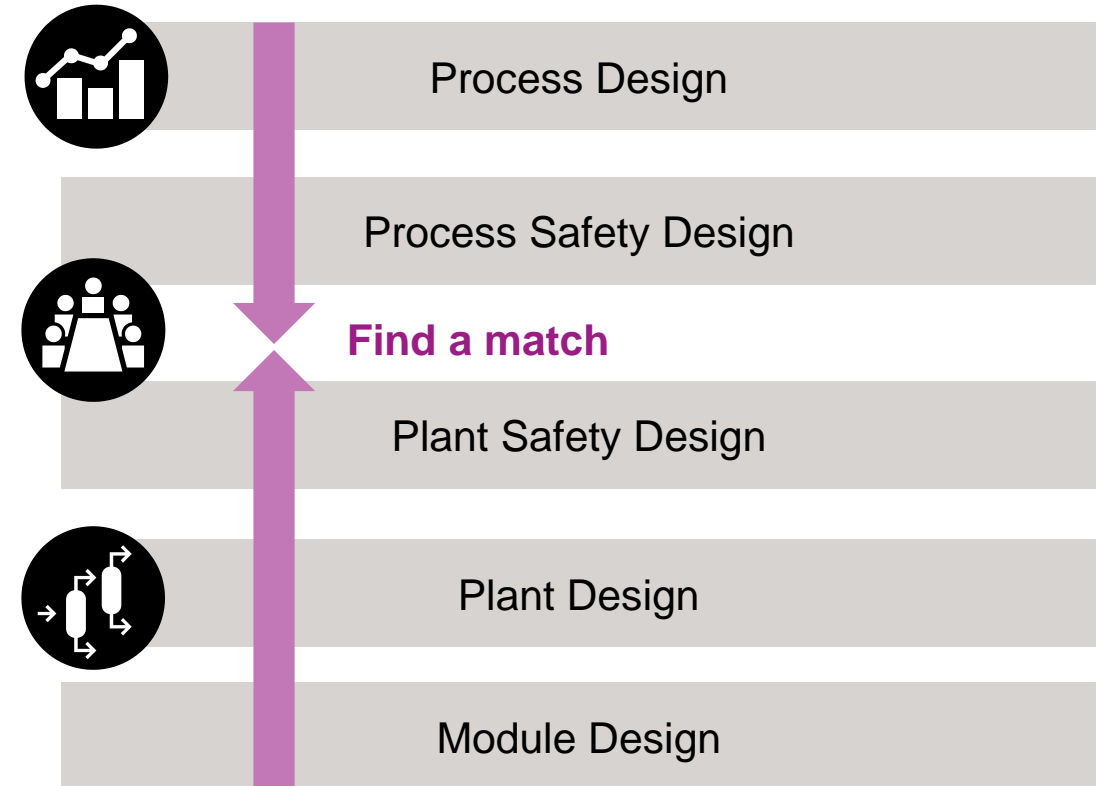
- Start with safety requirements and concepts in process design
- Match Module and Plant Safety capabilities

- **Create safety from within**

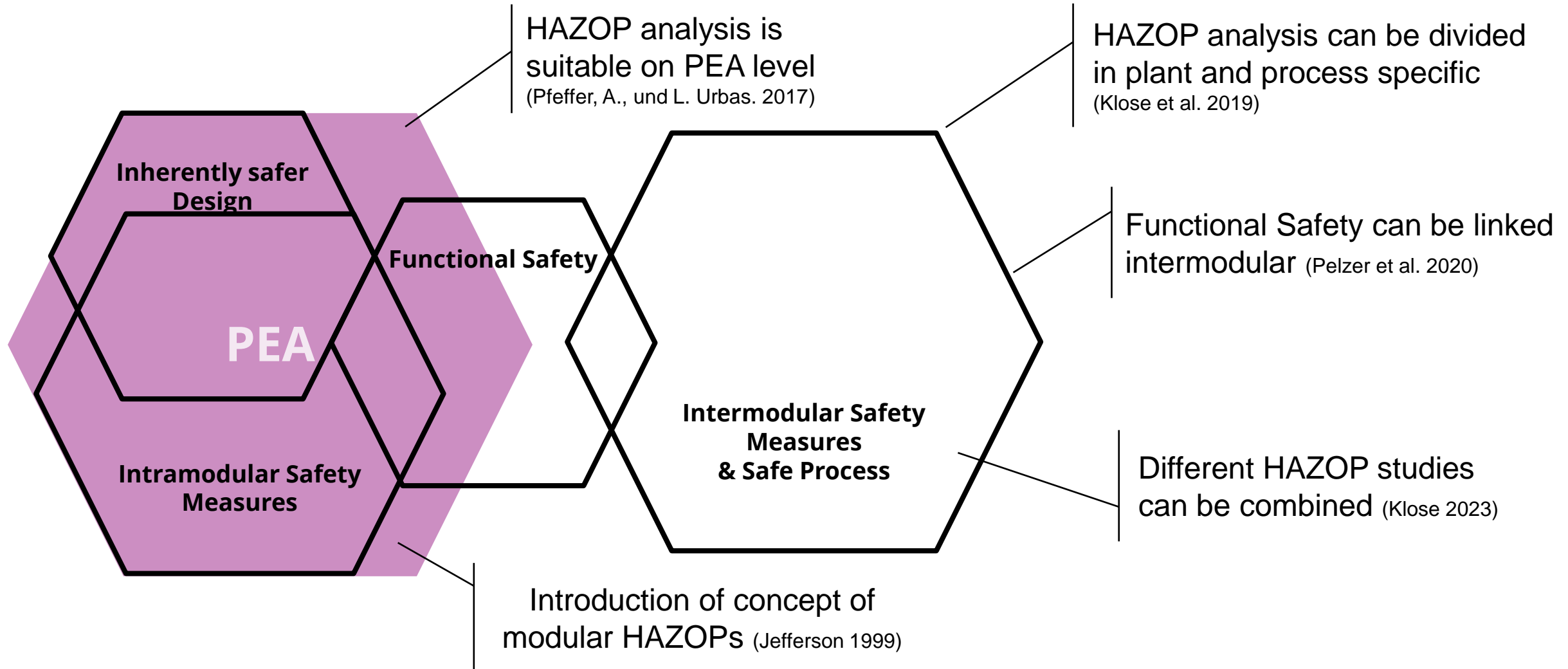
- Inherently safer design of modules, plant and process
- Special focus on interfaces to create safety barriers

- **HAZOP study can be on Module Level, combined to form overall plant study**

- Integration of specific process requirements



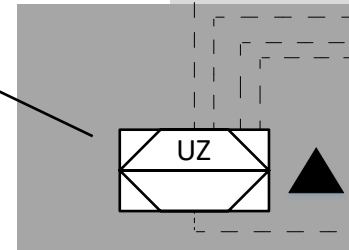
State of research for modular Safety Analysis



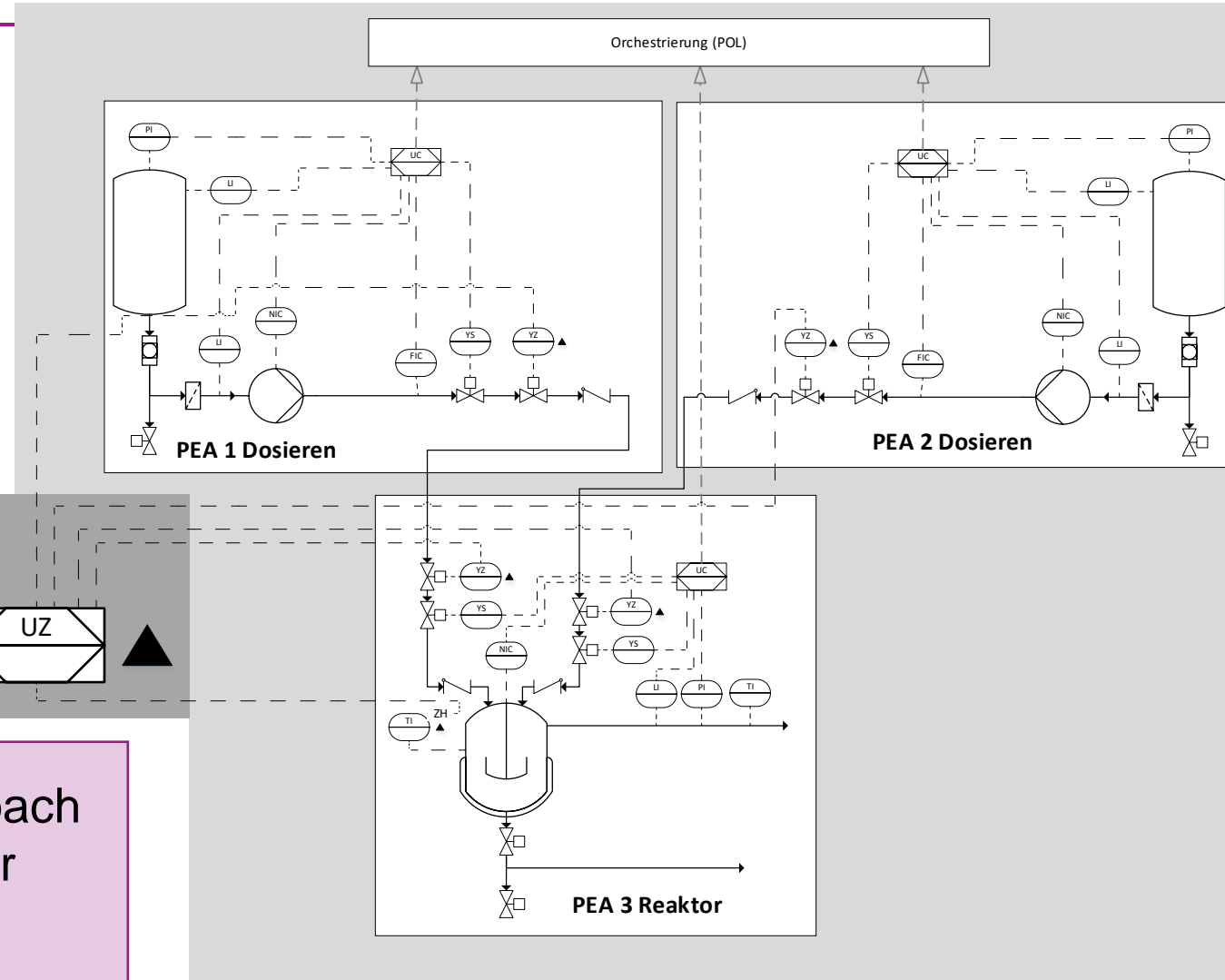
Conventional Safety for Modular Plants

- Different strategies show variety of solutions
 - Suitability of “conventional” solutions depend on application
- Open safety loops needs to be checked for each change

Conventional Safety System

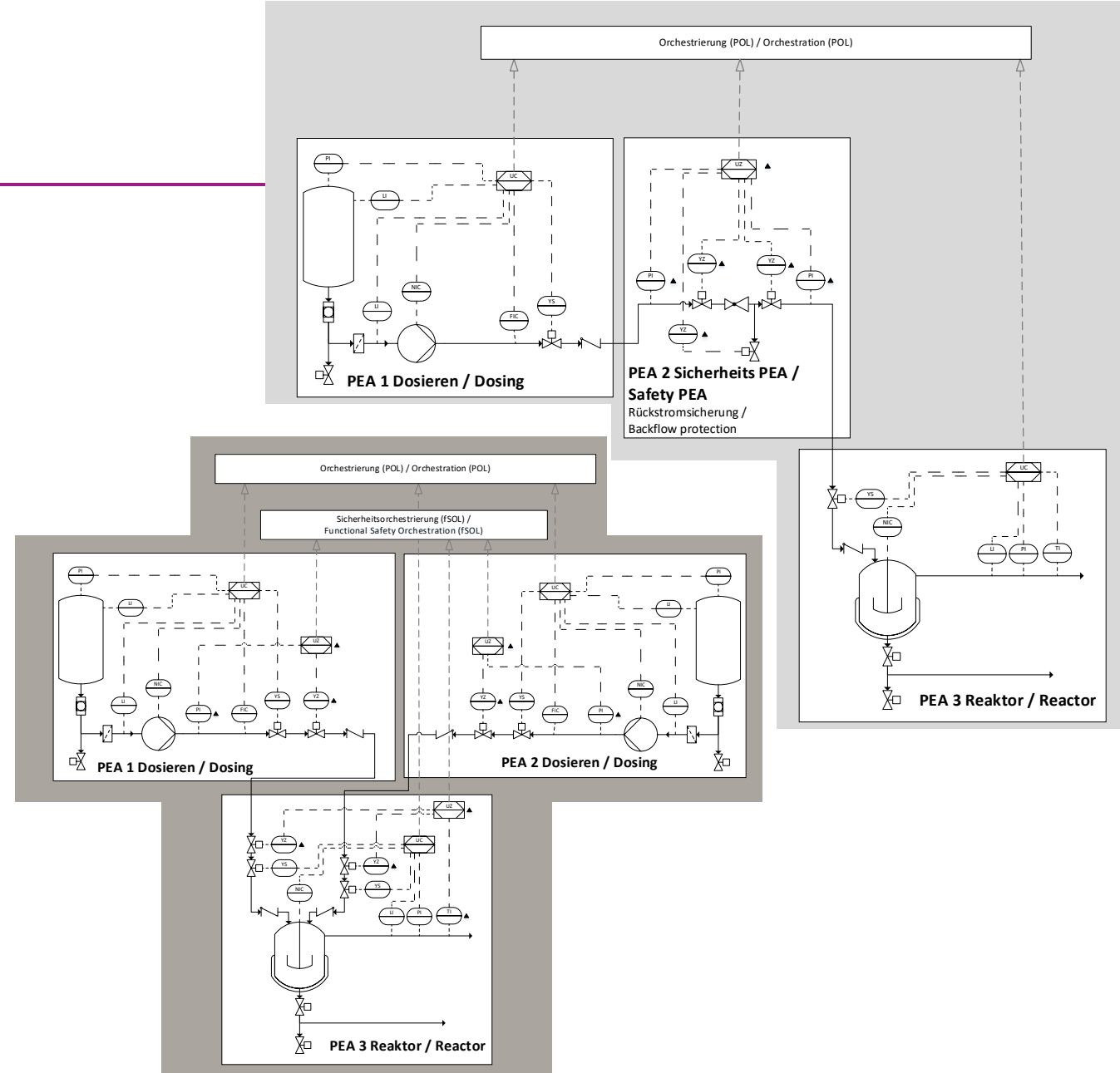


→ There is an additional Modular approach which fulfills requirements of modular automation and conventional safety



VDI 2776 – 3 Modular Safety Strategies

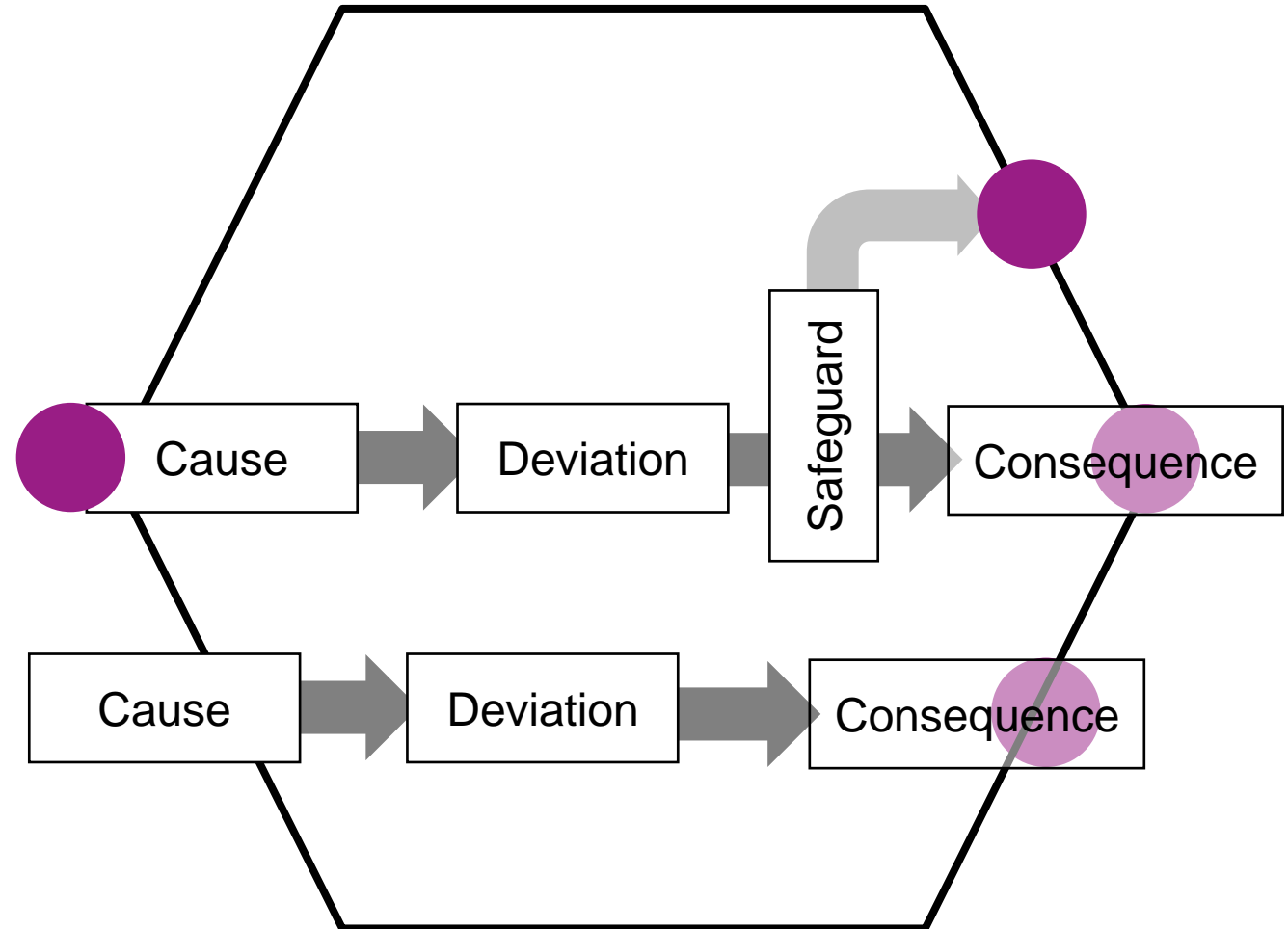
- **Insertion of additional “safety” modules**
 - ⊕ Can be implemented with conventional methods
 - ⊖ Increased equipment costs
- **Protection through comprehensive infrastructure**
 - ⊕ Can be implemented with conventional methods
 - ⊖ Flexibility and speed reduction
- **Interconnecting the functional safety systems of individual PEAs**
 - ⊕ Flexible connections possible
 - ⊖ Not yet available in standard form



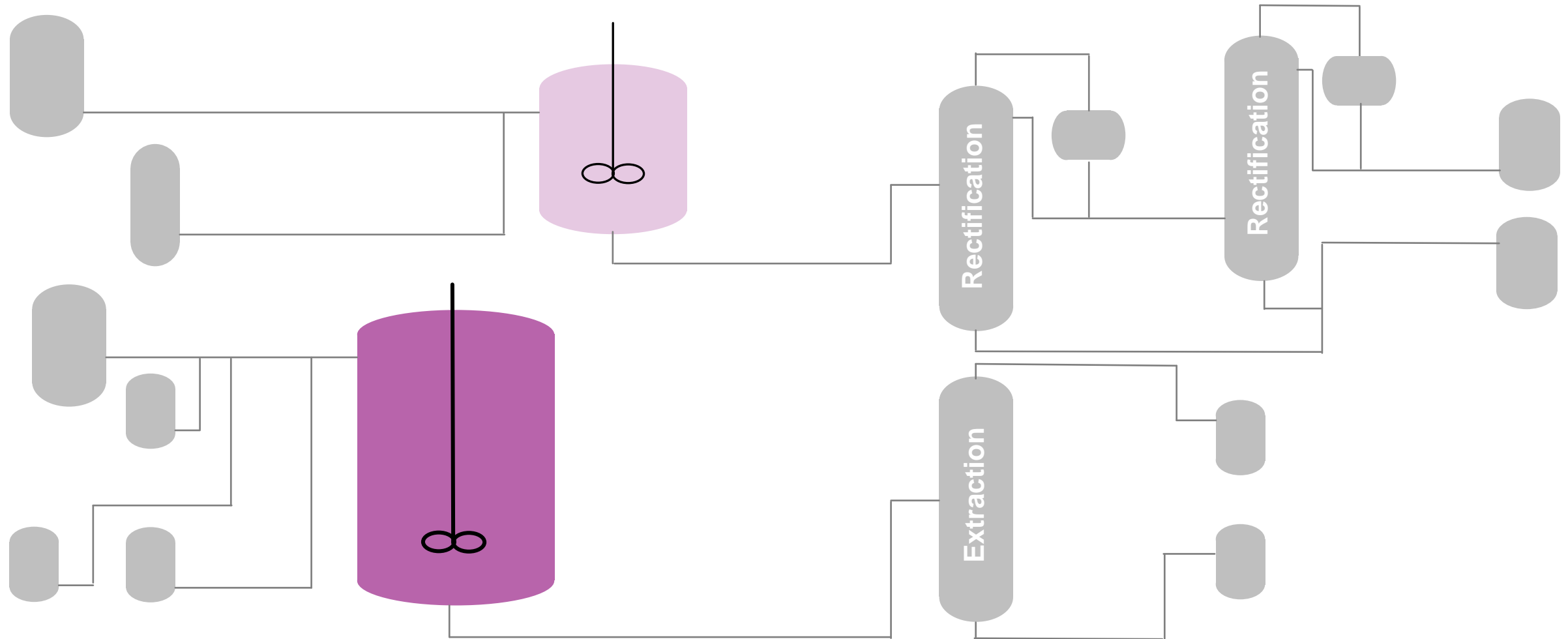
Persuing Modular Safety Strategies: From conventional to modular HAZOP

- **Definition of HAZOP Nodes in alignment with module interfaces**

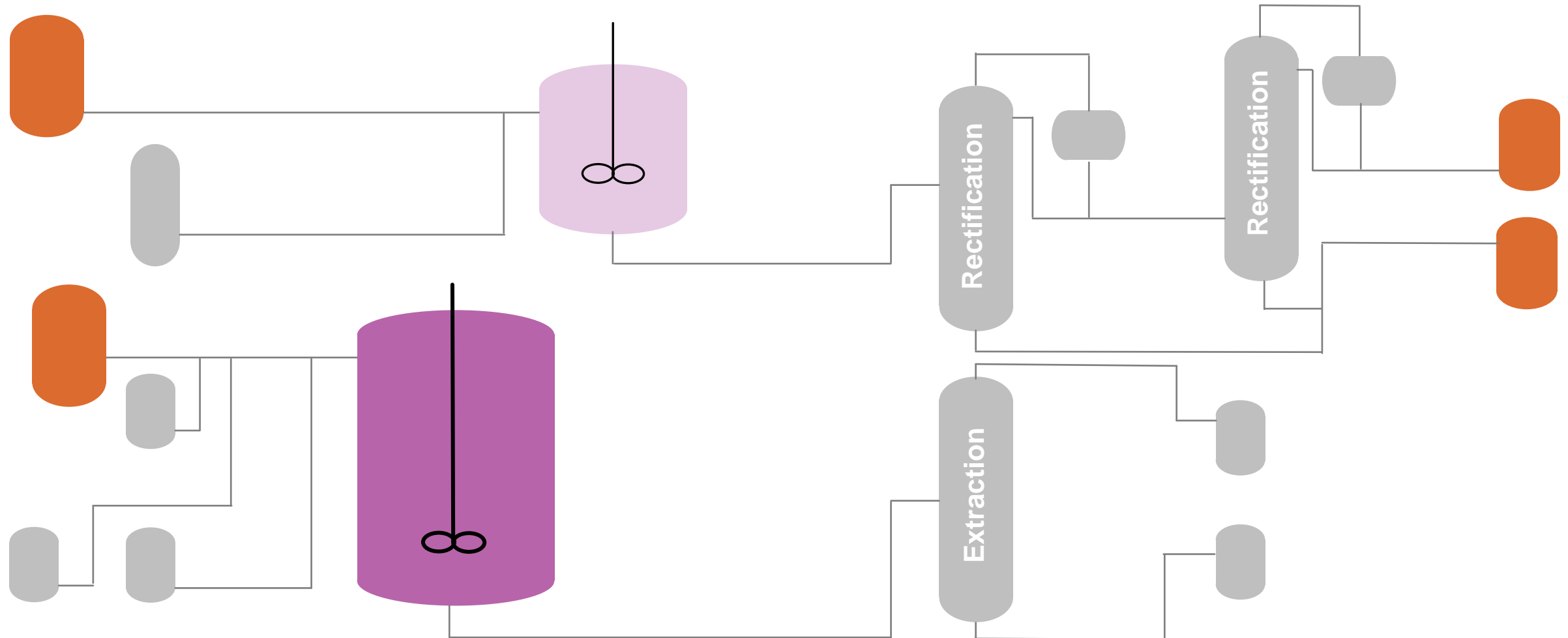
- Interfaces as essential viewpoint of HAZOP study
- Causes and Consequences can reach over module boundaries
- Safety concept shall minimize these risks



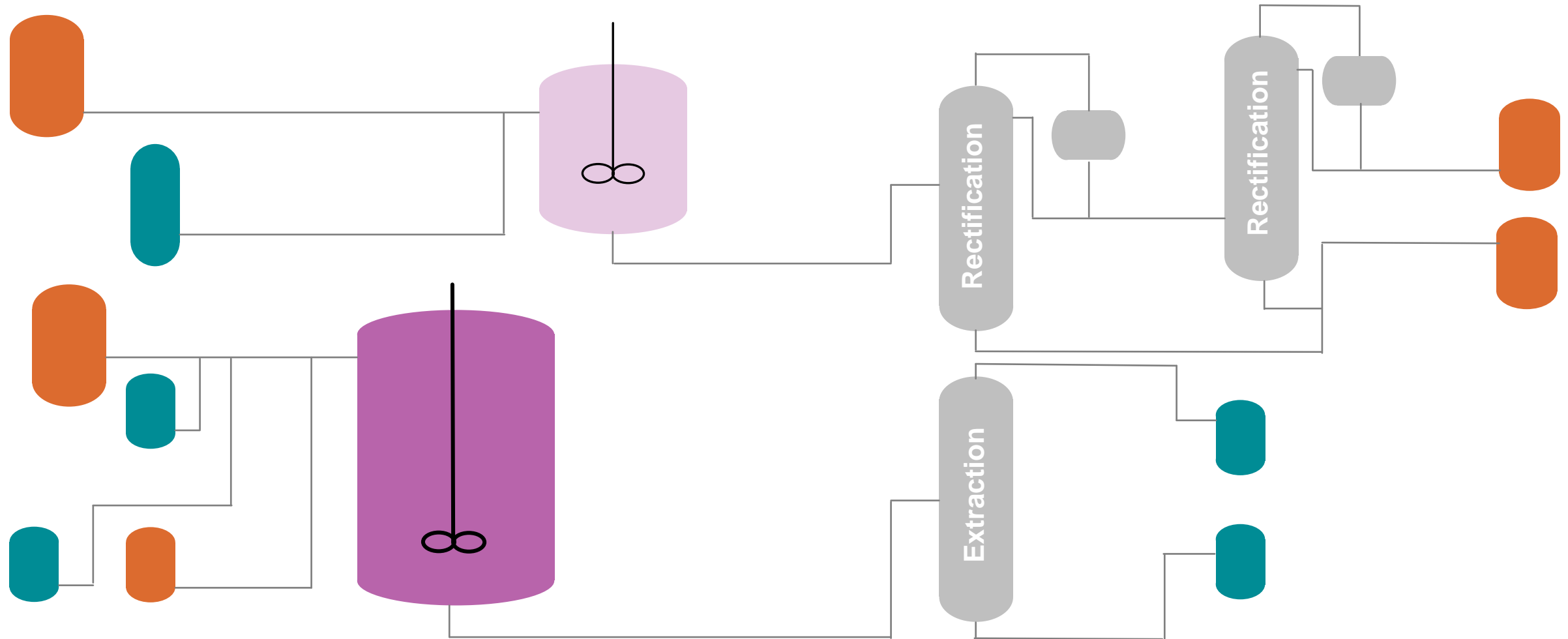
For similar unit operations in monolithic plants, modules on „Safety Concepts“ and „Safety Studies“ may be advantageous, too – also focussing on interfaces



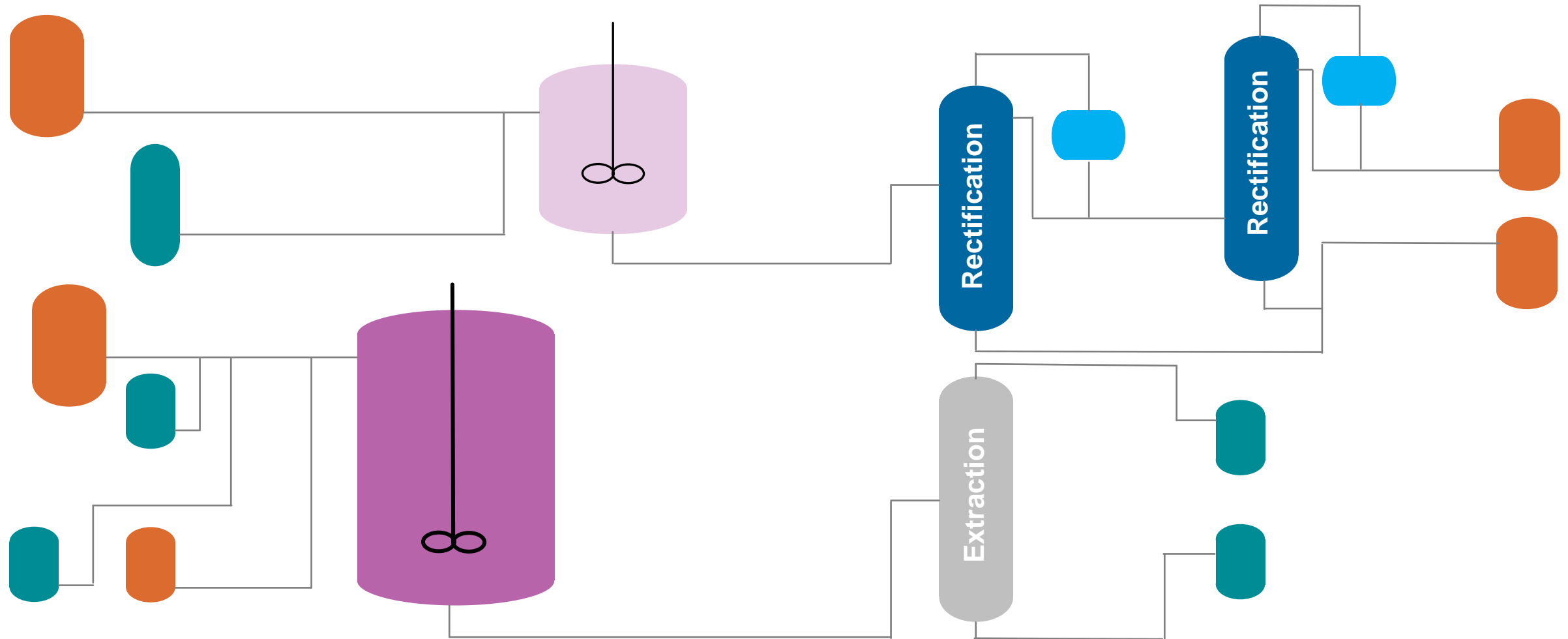
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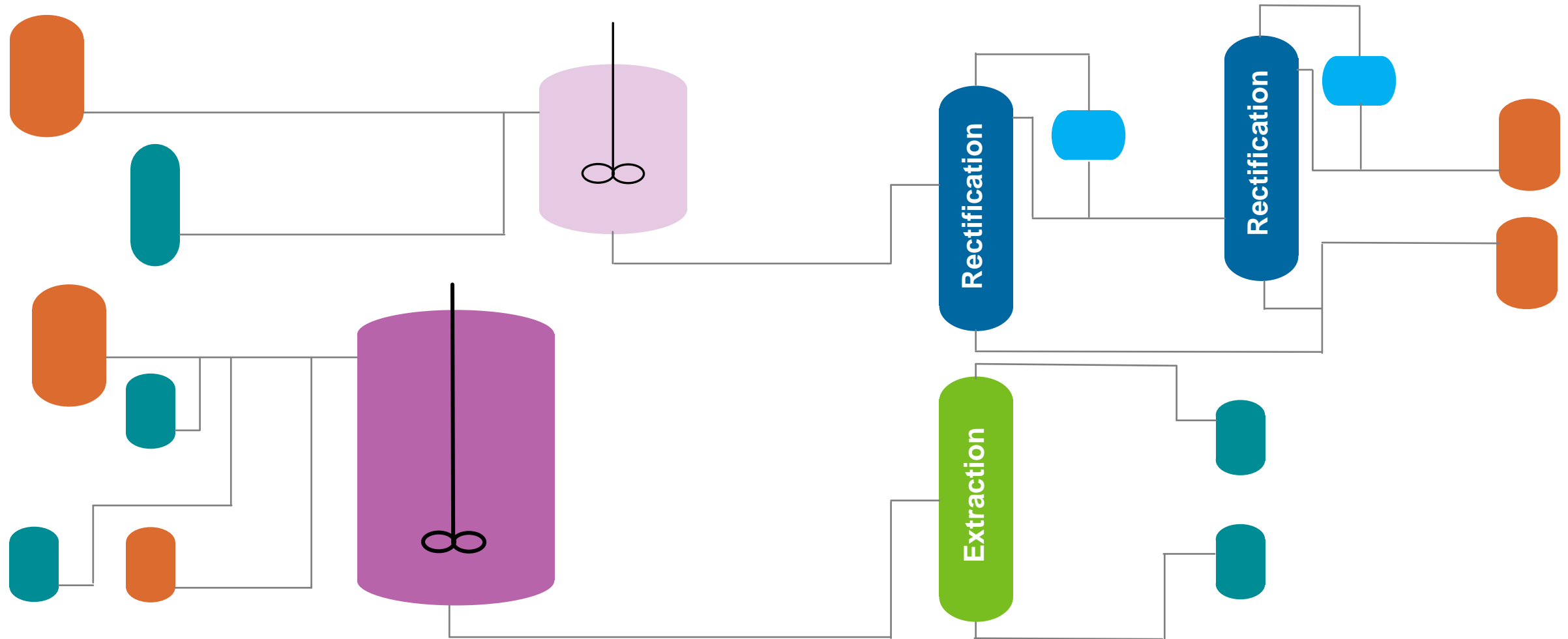
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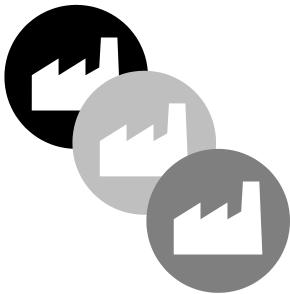
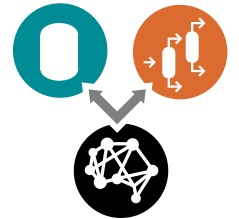
Ideas on Use cases for Modular Safety Concepts & Safety Studies (HAZOP)



▪ (Semi) Batch Processes

Per Unit Operation, e.g. supply, mixing vessel, product purification, product conditioning

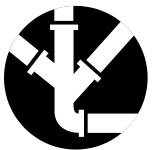
Overview and focus also on interfaces and interdependencies between units



▪ Analogous / „Sister“ Processes / Plants

Synergy and Comparability

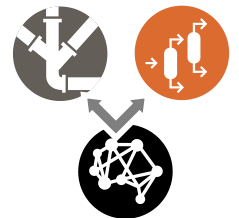
Challenge: realising and considering differences adequately



▪ Common Infrastructure

Synergy

Overview and focus also on interfaces and interdependencies with process systems



Comparison of efforts for conventional and modular HAZOP Studies

HAZOP-Efforts analyzed in Khan et al. 1997:

- Modular HAZOP Studies need more preparation efforts
 - High number of HAZOP Studies, higher number of P&IDs
- Modular HAZOP Studies can be less complex
 - Faster study time

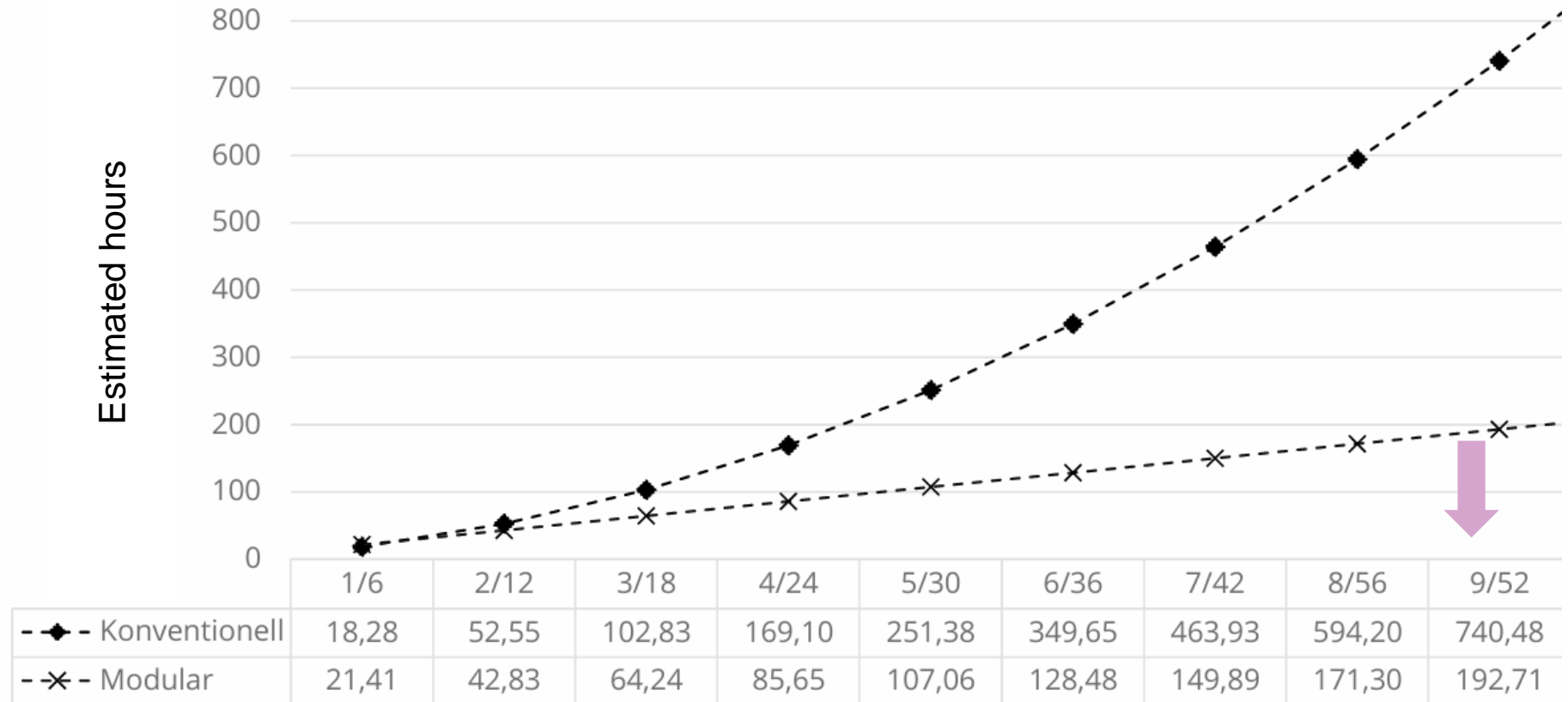
C_i : Complexity Factor [1..8]
 P_i : Complexity exponent [1..2]
 X_i : number of P&IDs (with certain complexity)

Constant factors

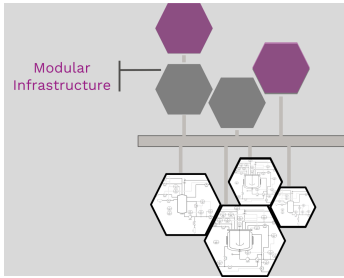
$$T_S = K \cdot L_{eff} \cdot \left(\sum_i C_i \cdot X_i^{P_i} \right)$$

Comparison of efforts for conventional and modular HAZOP Studies

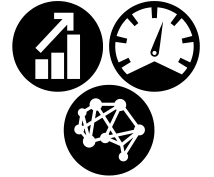
- For small process plants, modular HAZOP might be initial more effort
- For larger complex plants, efforts may increase exponentially, compared to modular HAZOP efforts
- By leveraging reuse of HAZOP studies, efforts can be further reused



Summary and Discussion



- Modular Plants enable**
 - more efficient and faster process and plant set-up
 - flexibility in process / product modifications and optimizations

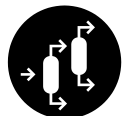


- Necessary basis for reliable and safe set-up and operation:**
Early holistic process and plant and safety Design



- The resulting sound process-engineering Safety Concepts are checked by Safety Studies**

- Providing flexibility and dependability by**
 - modular combination,
 - interface focusses and
 - thereby comprehensive view



- For analogous unit operations in monolithic processes and plants, the advantages of this modular Safety Concept and Safety Study approach may also be utilized.**



- Progresses in Digitalisation and machine-readable documentation offer new opportunities and support efficiently developing and reasonably implementing Modular Safety Concept and Modular Safety Studies**

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