Mixed-integer nonlinear programming models for optimal design of reliable chemical plants

—Problem statement

In this work we address a general modeling framework for production systems with underlying serial structures for availability evaluation (Figure 1). The goal is to determine design decisions regarding which potential parallel units to install, in order to maximize system net profit by balancing system availability (i.e. probability that the system performs without failures), which directly impacts system profitability, and the total cost for ensuring the availability level. In addition, we consider the bi-criterion optimization problem in which we maximize availability and minimize cost.

Sets of potential units \( j \in J_k \) for each stage \( k \) are given with:

- **Availabilities**, i.e. the probability of each unit being available.
- **Operating priorities** (indicated by \( j \)), which means that a unit can only become active when all installed units that have higher priorities have failed.
- **Cost rates**, including installation and repair.

Based on the parameters provided above, the relationship between the availability of stage \( k \) and the selection of parallel units is established. The processing stages are divided into two kinds:

- **Stages where potential parallel units are identical** \( (k \in K_{iden}) \).
- **Stages where potential parallel units have the same capacities, but are distinct in terms of availability or cost** \( (k \in K_{non}) \).