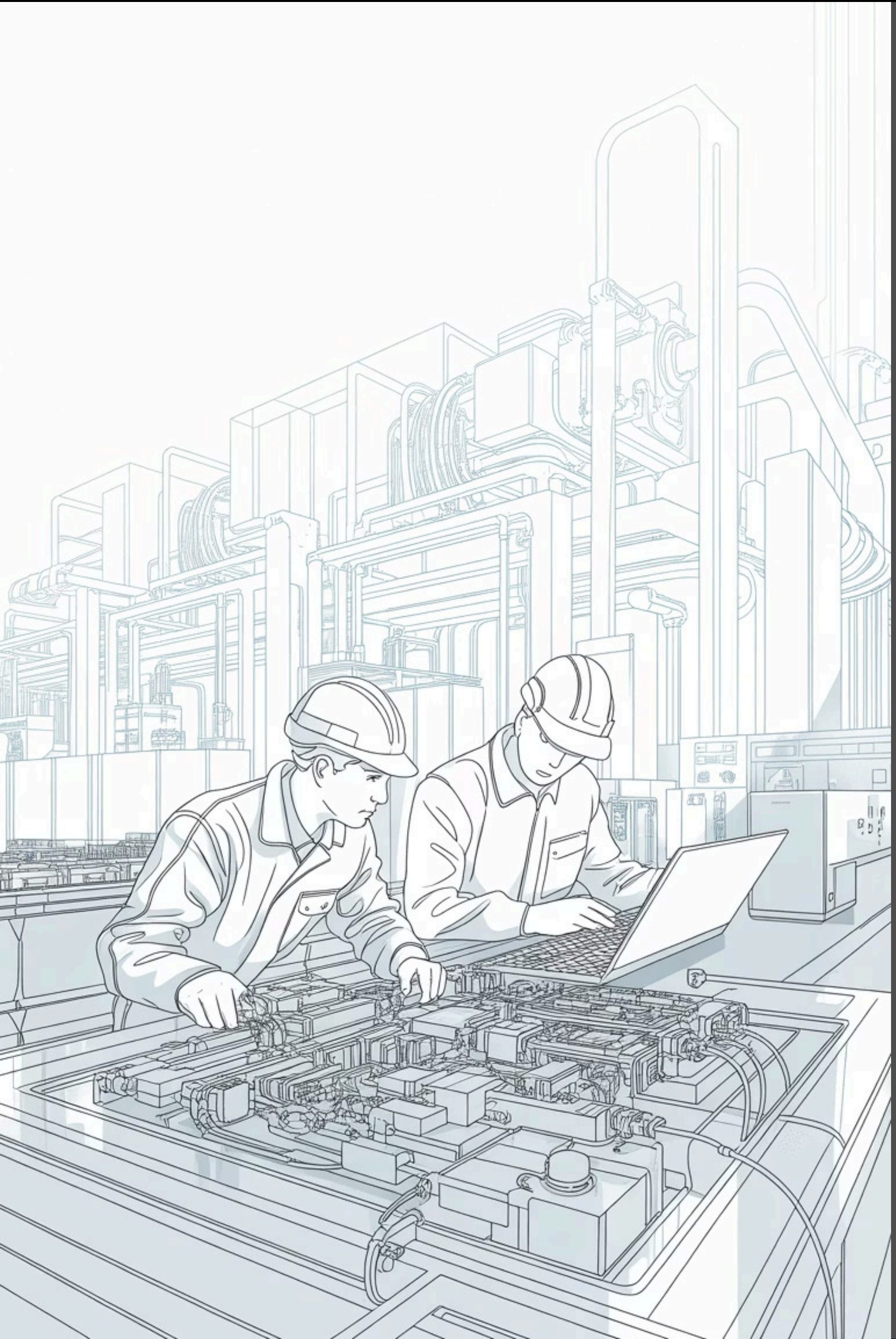
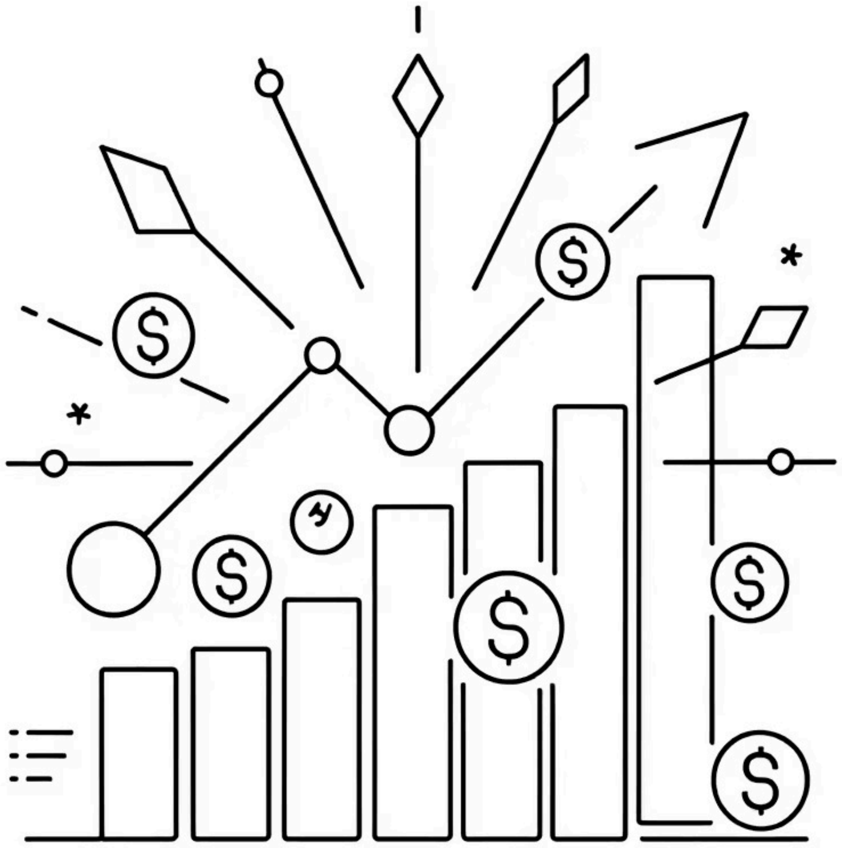


8.4.3 Exemple of algorithm use in MODAPTO:

Proposed Dynamic Grouping Algorithm (1)

Cost Functions

Quantifying the Financial Advantages



Economic Benefits of Grouping

The central principle driving our grouping approach is efficiency through resource consolidation. When maintenance activities are grouped strategically, significant cost reductions can be achieved through shared resources and reduced operational disruptions.

Setup Cost Sharing

Implementing a group of maintenance activities requires only one setup cost instead of multiple individual setups. This includes:

- Tool preparation and mobilization
- Specialized equipment deployment
- Technical documentation preparation
- Work permits and safety procedures

Downtime Consolidation

The system is halted once rather than multiple times, resulting in:

- Reduced production losses
- Decreased restart procedures
- Minimized quality stabilization periods
- Lower impact on delivery schedules

The economic savings from grouping can be expressed mathematically as:

$$\Delta C = \sum_{i=1}^{N_c} C_i^{PM} - \left(C_{\text{setup}} + \sum_{i=1}^{N_c} C_{i,\text{marginal}} \right)$$

This equation quantifies the difference between individual maintenance costs and the combined costs when activities are grouped, directly highlighting the financial benefit of strategic maintenance planning.

Anticipation and Postponement Effects

When grouping maintenance activities, we inevitably adjust the timing of some tasks from their individually optimal schedule. These adjustments have significant operational and financial implications that must be carefully modeled.

Anticipation Effects

Performing maintenance earlier than the individually optimal time introduces:

- Reduced component utilization (useful life not fully exploited)
- Increased frequency of replacements over equipment lifetime
- Higher inventory turnover of replacement parts
- Prevention of potential cascading failures
- Reduced risk of unplanned downtime

Postponement Effects

Delaying maintenance beyond the individually optimal time creates:

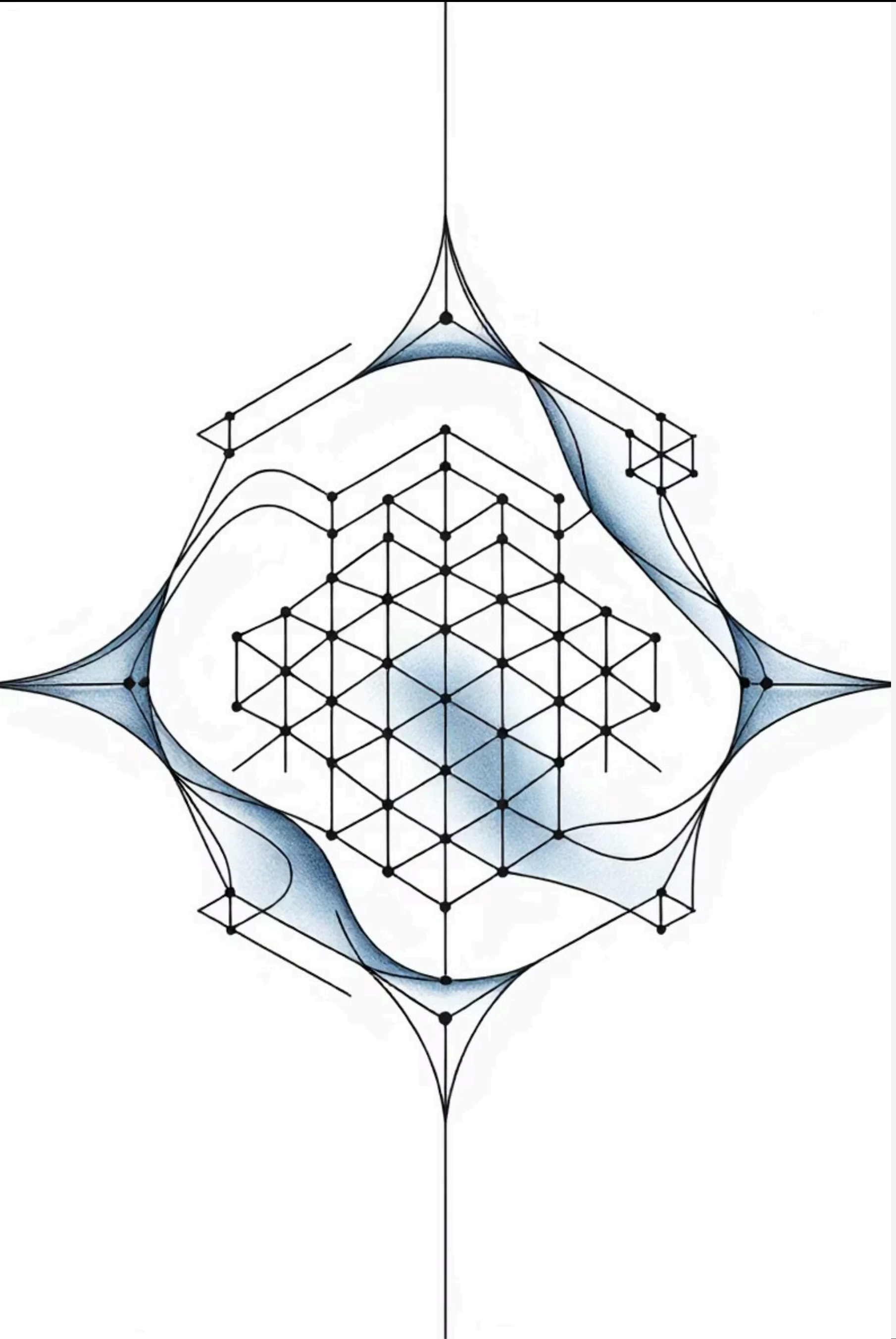
- Extended component utilization (maximizing asset use)
- Increased failure probability as components age
- Higher risk of catastrophic failure
- Potential for longer repair durations
- Risk of collateral damage to connected systems

Penalty cost function

We model these timing effects through a penalty cost function that quantifies the risk and inefficiency introduced:

$$C_{\text{penalty}} = \sum_{i=1}^{N_c} \left(P_i^{\text{anticipation}} + P_i^{\text{postponement}} \right) ntime$$

his penalty function creates a balance point between premature replacement costs and increased failure risks, guiding optimal maintenance timing decisions within grouped activities



Creating Optimal Maintenance Groups

Group Optimization

After quantifying the economic benefits and timing penalties, we proceed to the optimization phase where we determine which maintenance activities should be grouped together and when each group should be executed.

The optimization problem involves defining a set of groups (G_k) and their corresponding execution times (t_k) to minimize total maintenance costs while ensuring system reliability.

Decision Variables

- Group composition: which components belong to each maintenance group
- Execution timing: when each group should be scheduled
- Group quantity: how many distinct maintenance groups to create

Constraints

- Technical compatibility between grouped components
- Resource availability (personnel, tools, parts)
- Maximum allowable system downtime windows
- Minimum reliability thresholds
- Production schedule considerations

Optimization Goal

Minimize the total cost function while ensuring all components receive necessary maintenance within acceptable time windows, maximizing system availability and reliability.

The complete decision vector for the optimization problem can be expressed as:

$$x = \{G_k, t_k \ \ \forall k\}$$

This vector encompasses both the composition of each group and its scheduled execution time, forming the complete maintenance planning solution.

Total Cost Function

Our optimization approach seeks to minimize a comprehensive cost function that captures all relevant financial aspects of maintenance grouping. This objective function balances immediate maintenance expenses against long-term operational impacts.

The total cost function integrates four primary cost components:

$$\min C_{\text{total}} = \underbrace{C_{\text{setup}} \cdot |G|}_{\text{Setup costs}} + \underbrace{\sum_{i=1}^{N_c} C_{i,\text{marginal}}}_{\text{Marginal costs}} + \underbrace{C_{\text{penalty}}}_{\text{Timing penalties}} + \underbrace{C_{\text{downtime}}}_{\text{Lost production}}$$

Setup Costs

Fixed costs incurred each time a maintenance group is executed, including preparation, planning, documentation, and equipment isolation procedures. Multiplied by the number of groups to give total setup costs.

Marginal Costs

Variable costs directly associated with maintaining each specific component, including replacement parts, consumables, and component-specific labor requirements.

Timing Penalties

Costs arising from deviating from the individually optimal maintenance time for each component, reflecting both anticipation inefficiencies and postponement risks.

Downtime Costs

Production losses and operational impacts from system unavailability during maintenance execution, including lost throughput, quality issues during restart, and delivery delays.

This structured cost function provides a comprehensive framework for evaluating different grouping strategies and identifying the optimal maintenance schedule that minimizes total lifecycle costs.