

Optimisation of Preventive A-check Maintenance Tasks

Integrated and Distributed Approaches

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Introduction

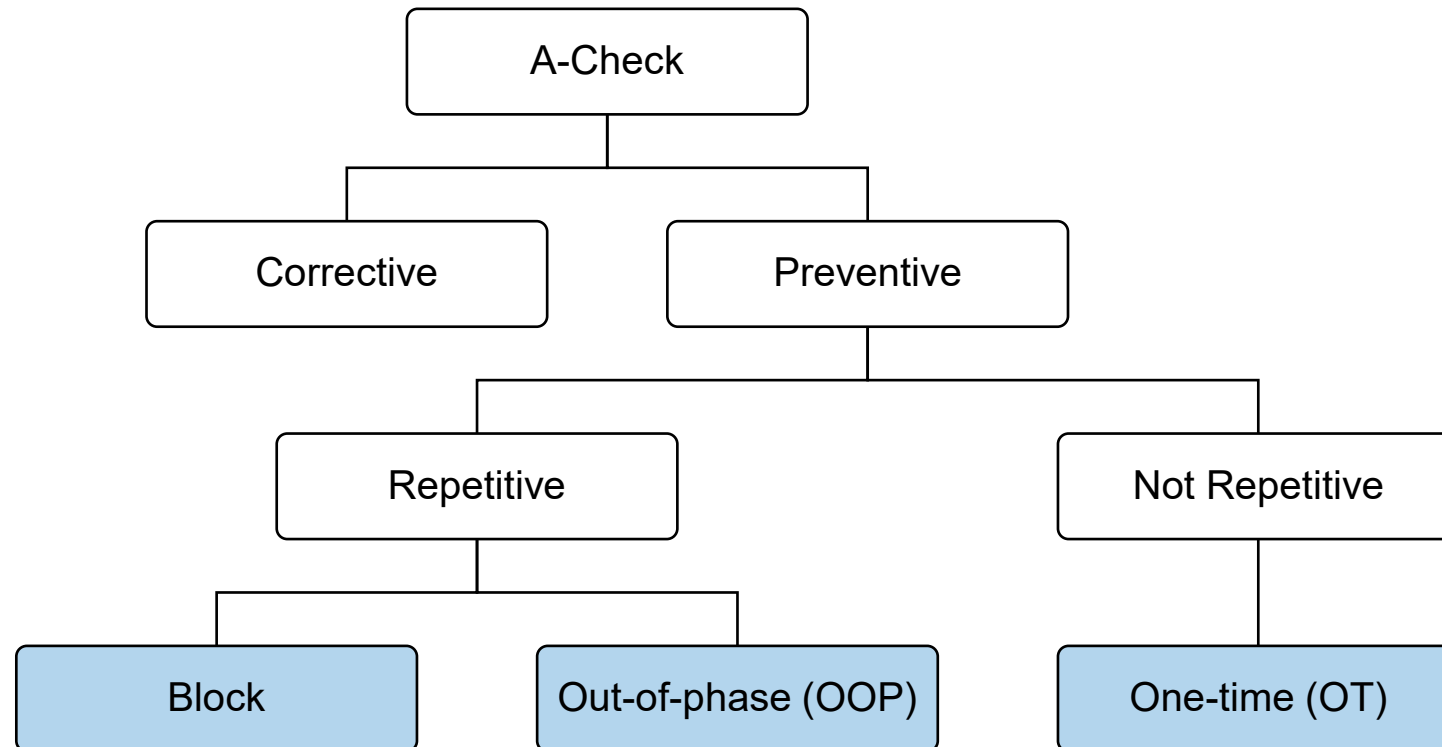
- MRO costs account for as much as **11% of global airline operational expenses** [1].
- Airlines group tasks according to their nature and periodicity in so-called letter checks.
 - A-checks, the lightest (6-24 hours every 2-3 months)
 - D-checks, the heaviest (3-6 weeks every 6-10 years)
- Our work focuses on A-checks

[1] International Air Transport Association (IATA). Airline maintenance cost executive commentary, 2023.

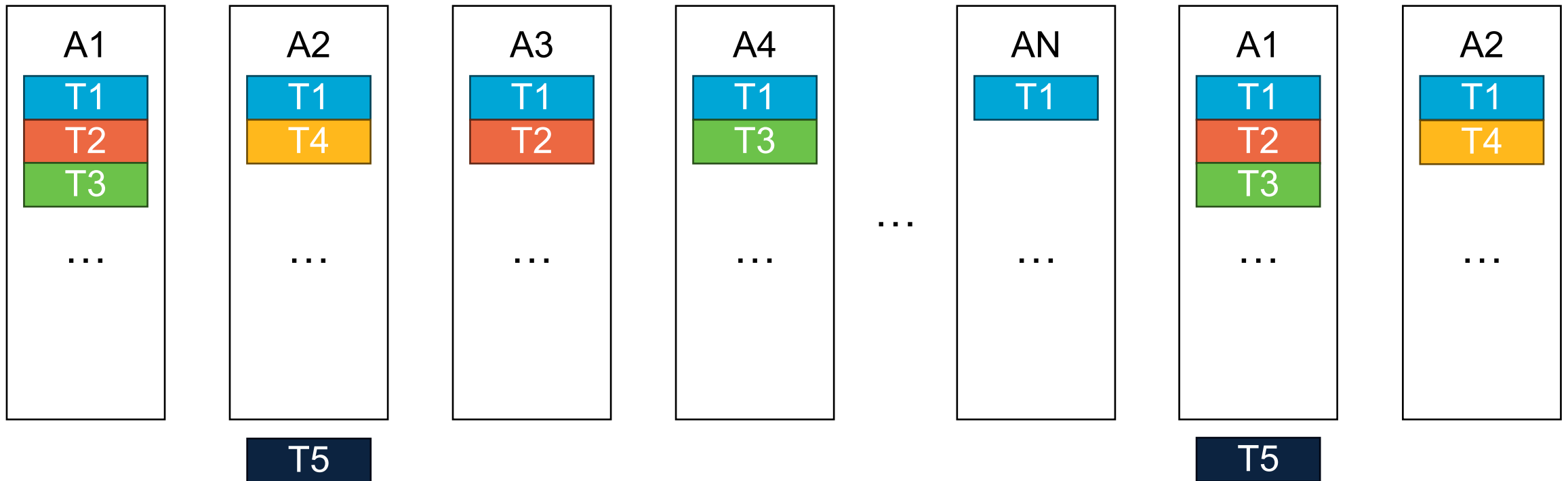
Central vs Distributed

- Maintenance planning is inherently complex and fragmented
- Within an airline, different teams optimise locally for specific time horizons, task groups and specific subfleets.
- Decisions cascade in **trickle-down fashion**
- Main airline challenges are:
 1. Modelling operational problem as optimisation tasks
 2. Defining interface and manage interactions between planning stages

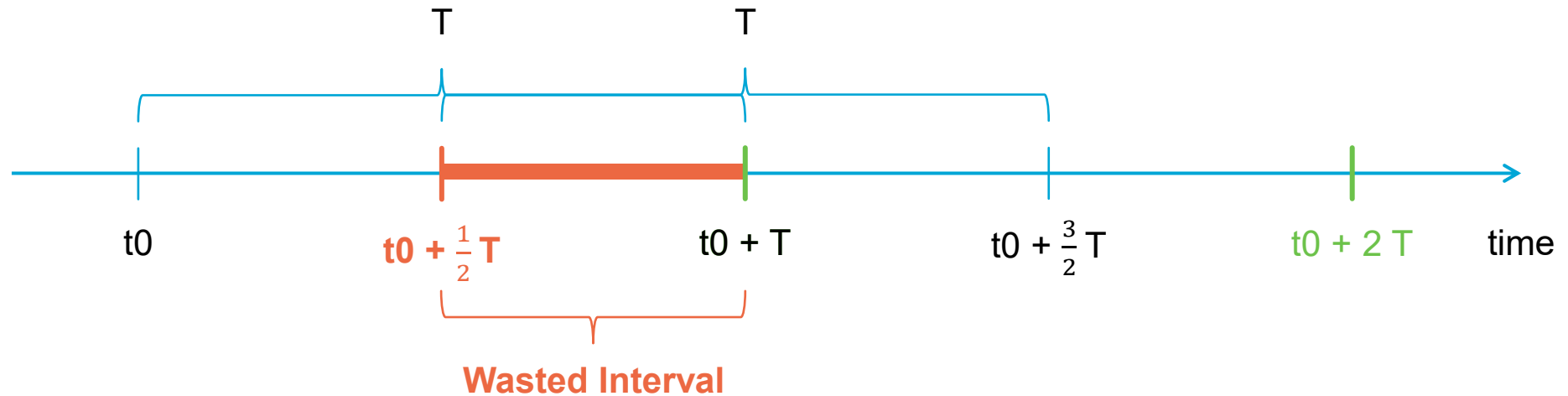
Task Types



A-Check Blocks



Interval Waste / Spillage



Task due date - Scheduled maintenance date

Research Objectives

01 Novel model to optimally assign individual A-check maintenance tasks to slots, for an entire fleet and operational season.

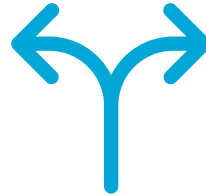
02 Decomposition of the model into separate components, locally optimising towards a global objective.

03 Comparison of integrated vs distributed approaches with a case study with real data from a major European airline.

Integrated Scheduler



Objective



Decision
Variables



Constraints

Objective

1. Schedule as many tasks as possible = minimise task deferrals
 2. Schedule repetitive tasks close to due date = minimise wasted interval (spillage)
 3. Schedule one-time tasks ASAP = minimise time to start of one-time (OT) tasks
- Sub-objectives are inherently conflicting.
 - Objective function is a weighed linear combination of sub-objectives.

Decision Variables

- as – aircraft-slot (Boolean) – whether an aircraft is assigned to a slot
 - e.g. $as_{(\text{aircraft } A, \text{ slot } S)} = 1$, aircraft A **is** assigned to slot S
- ts – task-slot (Boolean) – whether a task is assigned to a slot
 - e.g. $ts_{(\text{task } T, \text{ slot } S)} = 0$, task T **is not** assigned to slot S
 - if $ts_{(\text{task } T, \text{ slot } S)} = 0$ for every slot then the task is **deferred**

Constraints

- Max 1 aircraft can be assigned to one slot
- Tasks can only be assigned to a slot if respective aircraft is assigned to that slot
- Tasks can only be assigned before due date
- Tasks are either assigned or deferred
- Slot labour capacity cannot be exceeded

Distributed Schedulers

Three different architectures, each handling shared resources differently:

Mode 1

Aircraft-Slot

Mode 2

Slot Capacity

Mode 3

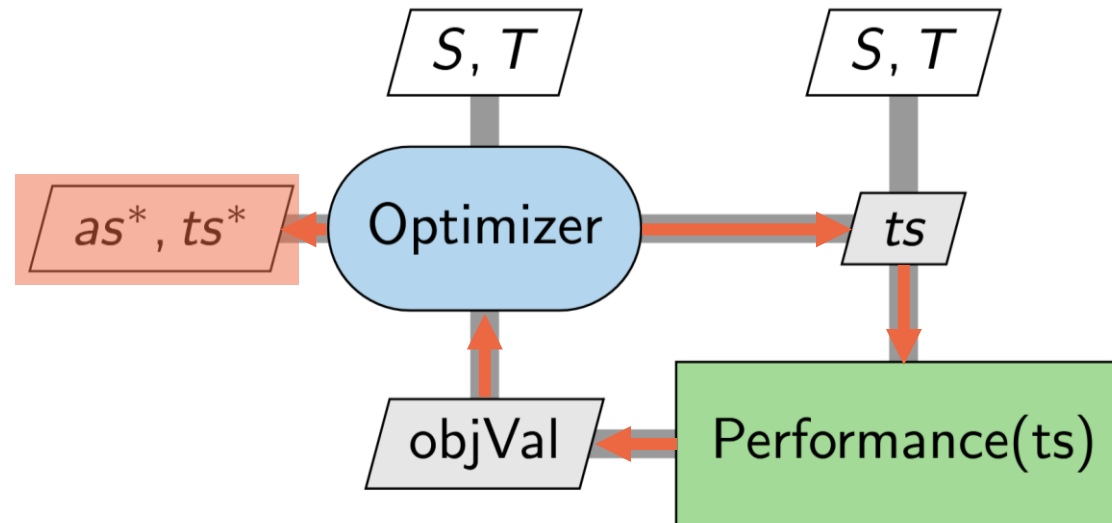
Aircraft-Slot

Slot Capacity

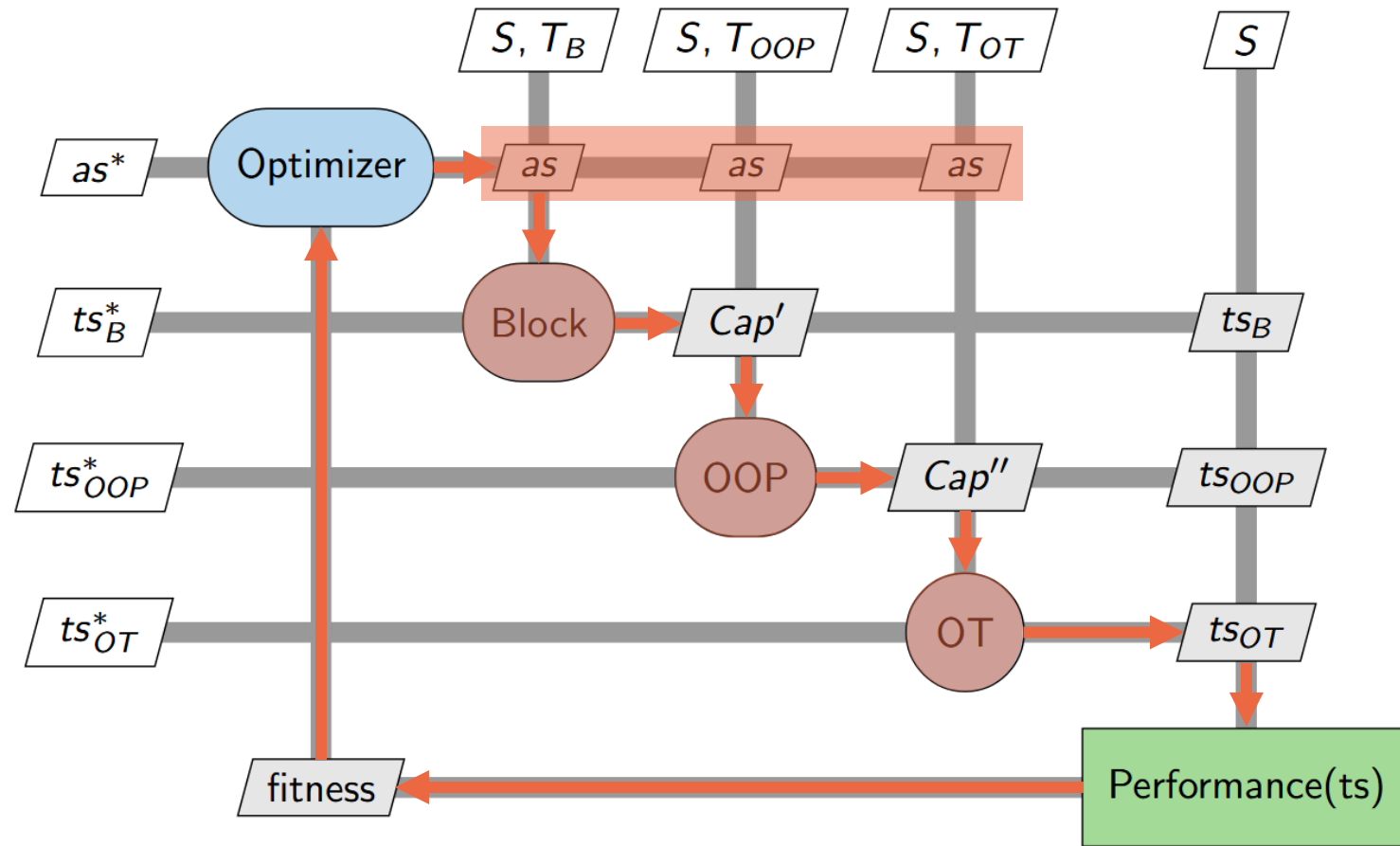
Local schedulers only allocate tasks of a single type (e.g. Block)

Global optimizer (employing a genetic algorithm) determines the shared resource allocation.

Integrated Approach



Mode 1 – Aircraft-Slot



Modes Summary

Approach	MILP	GA	Top-level optimiser directly sets		
			Task-Slot	Aircraft-Slot	Slot Capacity
Integrated	✓		✓	✓	✓
Mode 1	✓	✓		✓	
Mode 2	✓	✓			✓
Mode 3	✓	✓		✓	✓

Case Study

- Real maintenance data from major airline
- Two datasets of tasks (Block, OOP and OT) and maintenance slots
- Each dataset covers an entire operational season
- Subfleet of wide-bodied passenger aircraft
- Dataset A has fewer slots and substantially more OOP and OT tasks, harder problem than Dataset B.

Results – Dataset A Summary

Metric	Deferrals Block	Deferrals OOP	Deferrals OT	Wasted Interval (days)	Time to start (days)
Historical				34.464	76.916
Integrated	0	23	130	33.350	46.172
Mode 1 (AS)	0	76	152	35.754	50.750
Mode 2 (Cap)	0	102	298	46.205	56.370
Mode 3 (AS+Cap)	0	403	390	53.777	54.590

Discussion

- Central planner outperforms distributed approaches.
 1. Rigidity and strong inter-dependencies in problem at hand
 2. Limitations in our distributed designs
 3. Generic nature of GA
 4. Inaccurate estimates of task resource requirements and slot capacity
- Shifting greater control from domain-specific local planners to generic global optimiser worsens performance.

Conclusion

01 Integrated scheduler produces schedules (minutes) that are of comparable quality to those crafted by experienced planners (several weeks).

02 Integrated scheduler outperforms distributed approaches.

03 Decision-support tool

Future Work

- Incorporate domain-specific knowledge into global GA
- Shift away from hierarchic approach with cascading decisions into more flexible multi-agent formulations.
 - Local optimisers collaboratively propose partial solutions and negotiate for shared resources.
 - Conflict resolution.

Thank you!