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DMAN-SMAN-AMAN Optimisation at Milano Linate Airport

Giovanni Pavese, Maurizio Bruglieri, Alberto Rolando, Roberto Careri
Politecnico di Milano

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Introduction

Every single study predicts an impressive air traffic growth over the next decade(s)

Year (SESAR-2020 horizon)	Traffic increment wrt 2017
2023	+14%
2035	+40%

In the medium-long term it will be **impossible to accommodate the expected flights** with present infrastructures and services.

SESAR Solutions: Departure MANager (DMAN), Arrival MANager (AMAN), Surface MANager (SMAN), Airport – Collaborative Decision Making (A-CDM).

Departure MANager (DMAN)

Present procedure: First Come First Served (FCFS)

- controllers authorize A/C to start up and taxi to the runway as soon as ground handling operations are concluded;
- traffic flow is not smooth: queues, delays, uncertainty, unnecessary fuel burning and noise emissions.

DMAN procedure:

- determines departure sequence at the runway computing the **Target Take-Off Time (TTOT);**
- determines pre-departure sequence computing the **Target Start up Approval Time (TSAT),** starting from the runway and going back to the parking stand.

DMAN considers:

- scheduled departure times;
- EU departure slots constraints;
- local airport factors;
- wake vortex and instrumental procedures separations.

DMAN Advantages:

+ traffic awareness;
+ environmental sustainability;
+ safety;
- cost.

Arrival MANager (AMAN)

Present procedure: First Come First Served (FCFS)

- aircraft are separated and sequenced following their entry time in the TerMinal Control Area (TMA);
- if runway capacity is saturated, aircraft are obliged to hold in air before obtaining landing clearance.

AMAN procedure:

- determines the optimum approach/landing sequence computing the **Target Landing Times (TLDT)**;

AMAN Considers:

- scheduled arrival times;
- airport factors;
- wake vortex and ATC separations.

AMAN advantages:

+ traffic flow smoothness;
+ traffic awareness;
+ environmental sustainability.

Surface MANager (SMAN) and A-CDM

SMAN is an ATM tool that

- determines the optimal **taxi route** and **ground scheduling**;
- optimises the resource usage (e.g. de-icing facilities);
- + efficiency, + traffic awareness, + safety.

Airport – Collaborative Decision Making (A-CDM) is a ATM tool that

- is based on **information sharing** among airport **stakeholders** and on milestone approach.
- allows each airport player to optimise its decisions in **collaboration** with all others.

Integration between the DMAN, SMAN, AMAN, and A-CDM is fundamental for the global optimization of the airport system.

Description of the work

- Objective: design an optimisation algorithm to be applied at Milano Linate airport.
- Co-operation: ENAV Air Traffic Controller and SEA personnel.

  → Specific objectives, constraints and local procedures.

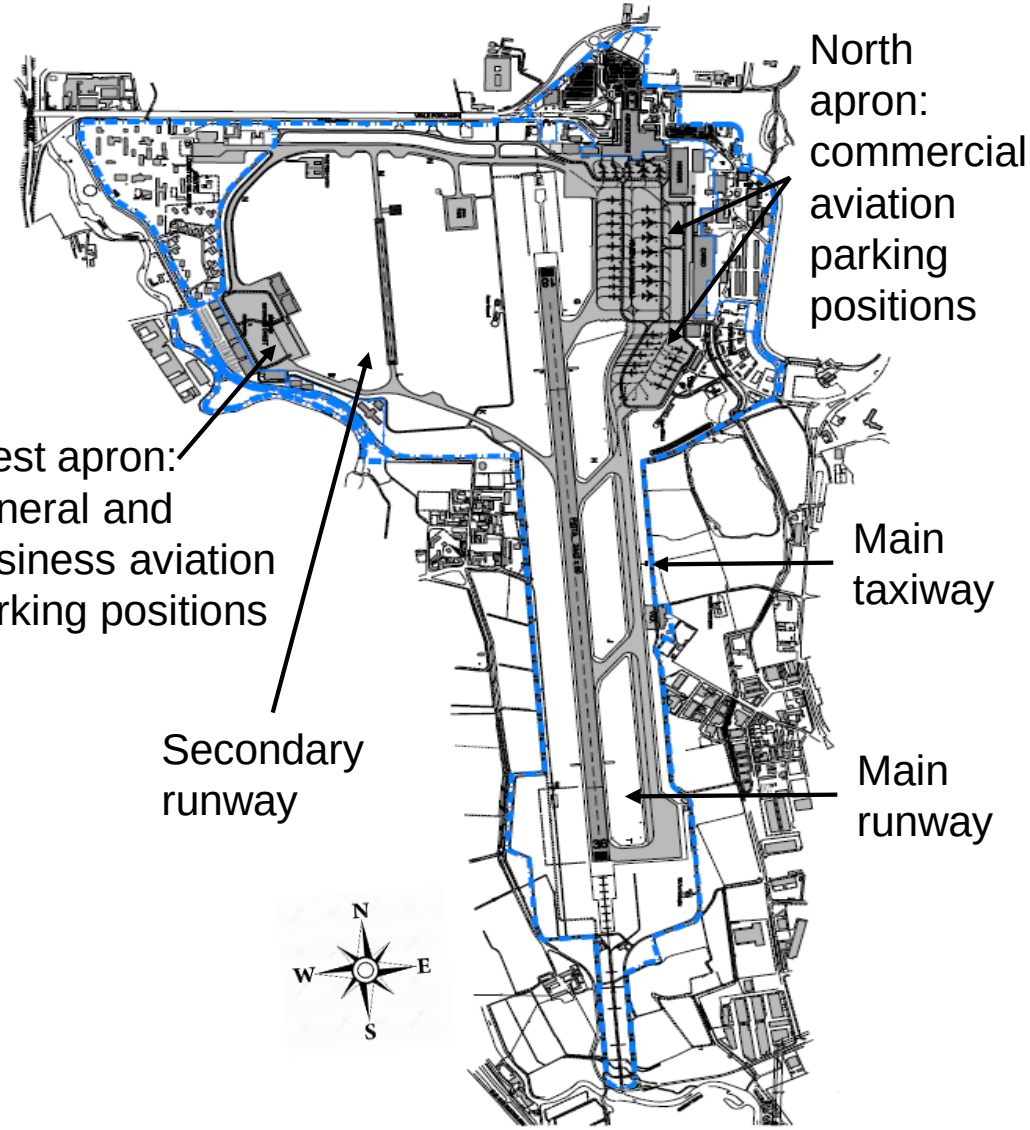
- Method: heuristic decomposition for solving integrated problem DMAN+SMAN+AMAN:
  - Step 1: ground routing problem (SMAN);
  - Step 2: runway scheduling problem (DMAN+AMAN);
  - Step 3: ground scheduling problem (SMAN).

  →
  - Airport traffic flow optimisation at **global** level.
  - Solution is **sub-optimal** but still gives good results.
  - Very **low** computational time (high dynamicity).

- Validation: comparison optimal data with real data of two case study days.

Milano Linate airport

- In Italian airport panorama (2016):
  - 3th for aircraft movements;
  - 4th for passenger traffic;
  - 8th port for cargo traffic;
- general, business and commercial aviation;
- **single main taxiway**: bottlenecks could be eliminated using an optimization algorithm for sequencing aircraft.
- **single runway**: mixed mode (take-off and landing) is challenging for the algorithm.



Step 1: ground routing problem (SMAN)

Objective: compute a **feasible route** for each aeroplane,
minimizing **taxi time** and trying to **exploit all airport resources**.

Constraints:

- assigned parking positions (by airport operator);
- airport topology (modelled with an oriented graph);
- tabulated taxi times (from ACDM platform).

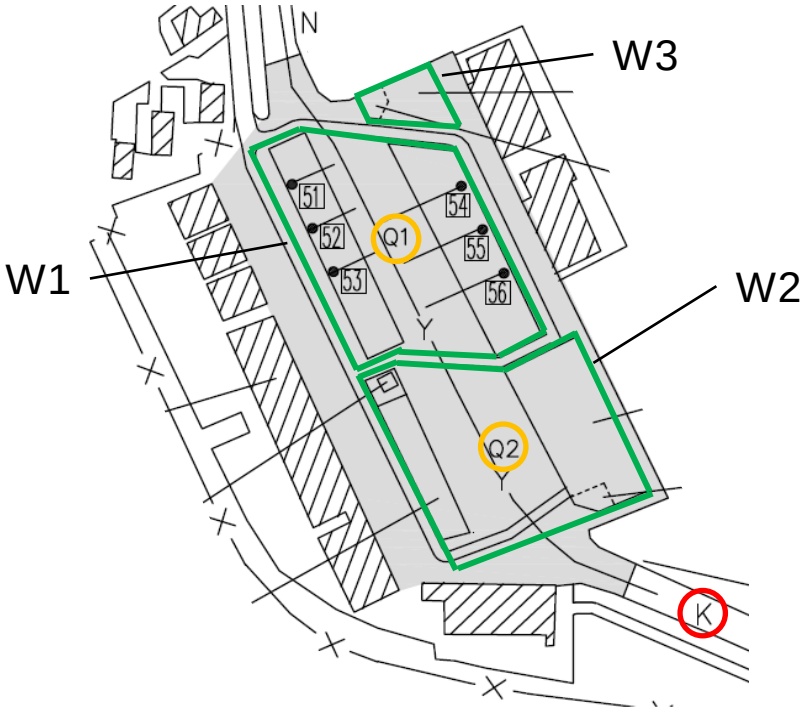
Modelling: Non Linear Programming (NLP) problem.

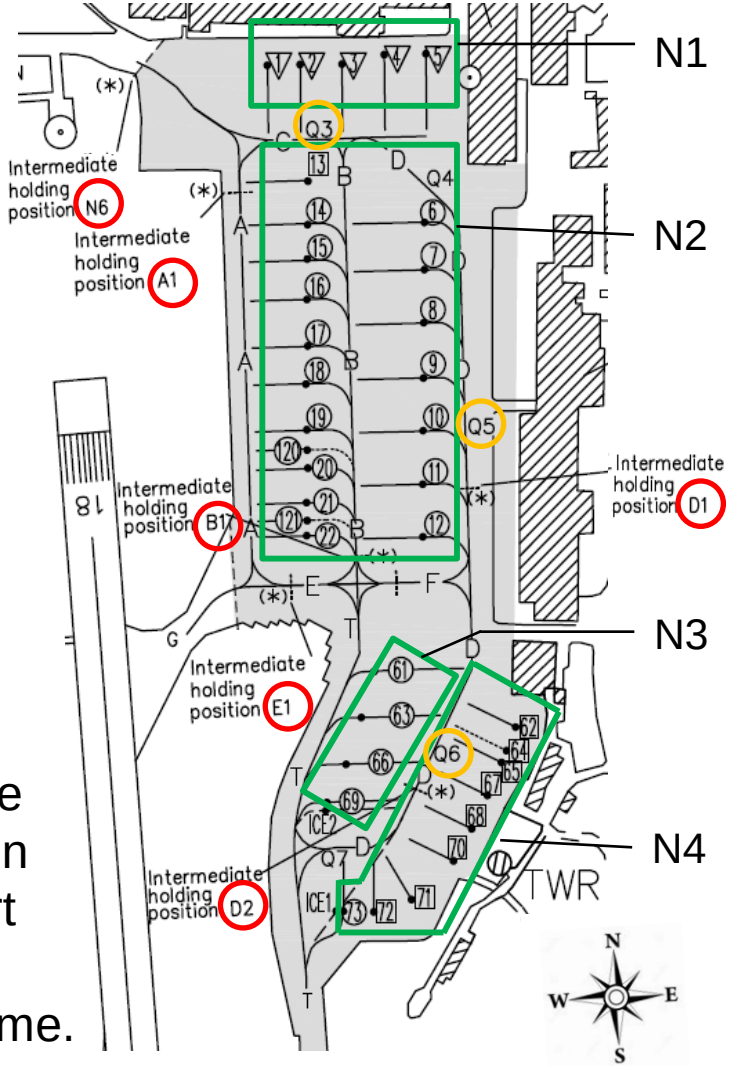
$$\min \sum_{f \in F} \sum_{a \in A} u_f^a \cdot \left(l_f^a + \underbrace{\frac{0.1}{\mathrm{card}(F)} \sum_{f \in F} u_f^a}_{\text{Taxi time cost due to arc usage.}} \right)$$

Binary variable: if equal to 1, the arc belongs to the optimal path.

Taxi time of arc a.

Step 1: ground routing problem (SMAN)

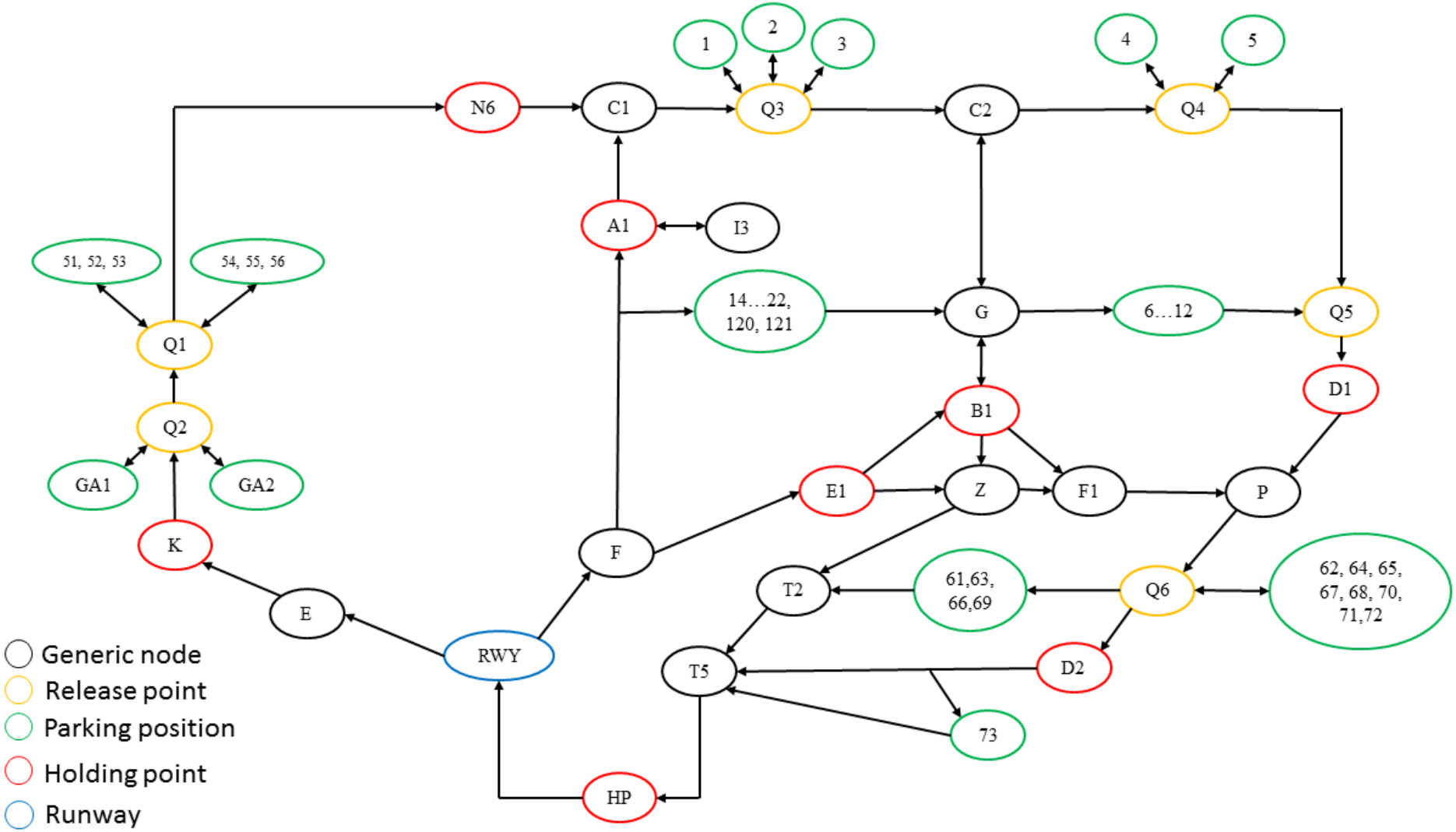




For each parking zone N_i and W_i, the expected inbound (EXIT) and outbound (EXOT) taxi time is taken from A-CDM.

EXIT and EXOT have been divided between the arcs of the airport graph and used to compute route taxi time.

Step 1: ground routing problem (SMAN)



Step 2: runway scheduling problem (DMAN+AMAN)

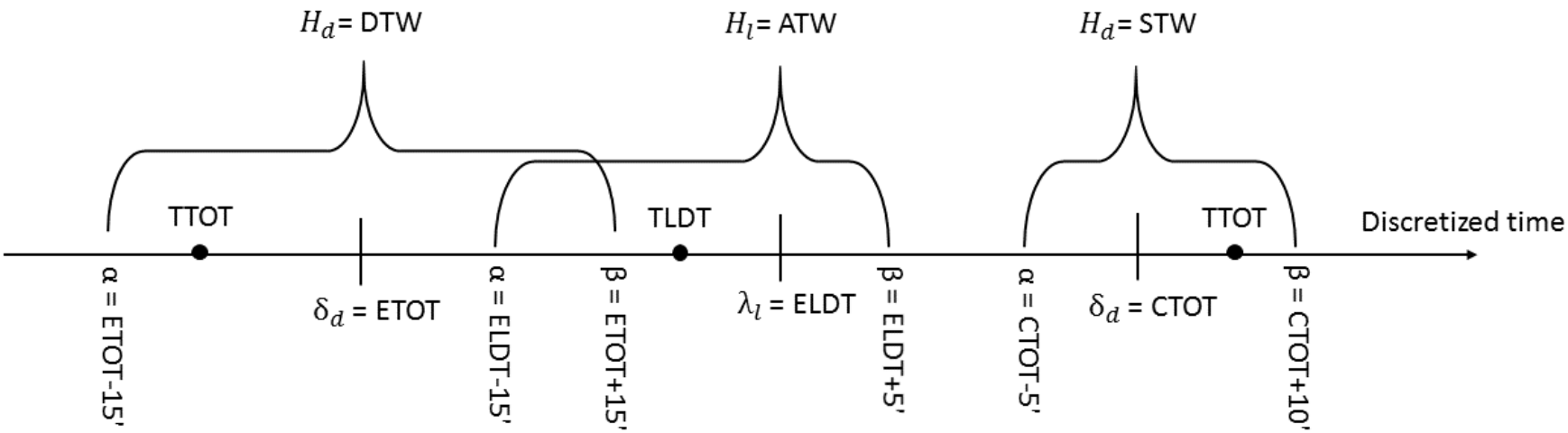
Objective: find an **optimal scheduling at the runway** for arrivals (**TLDT**) and departures (**TTOT**), minimizing deviation from desired arrival and departure times.

Constraints:

- tolerance windows (with respect to desired times)
- wake vortex separations (RECAT-EU);
- minimal RADAR distances (for arrivals) and SID procedures (for departures);
- departures with CTOT assigned must depart; the others can be dropped.
- arrivals must always land.

Modelling: Integer Linear Programming (ILP) problem.

Step 2: runway scheduling problem (DMAN+AMAN)



$$\min \sum_{d \in D} w_d \cdot y_d + \sum_{f \in F, t \in H_f} c_{ft} \cdot x_{ft}$$

Drop cost.

Deviation cost.

Binary variable: if equal to 1, the departure is **dropped** (can't depart within the DTW)

Binary variable: when equal to 1, indicates optimal **TTOT** and **TLDT**.

Step 3: ground scheduling problem (SMAN)

Objective: to compute a **conflict-free schedule** for each flight,

minimizing the time the aircraft spend between the parking position and the runway with engines on, and vice-versa.

→ Compute **TSAT** and **TIBT** (Target In-Block Time).

Constraints:

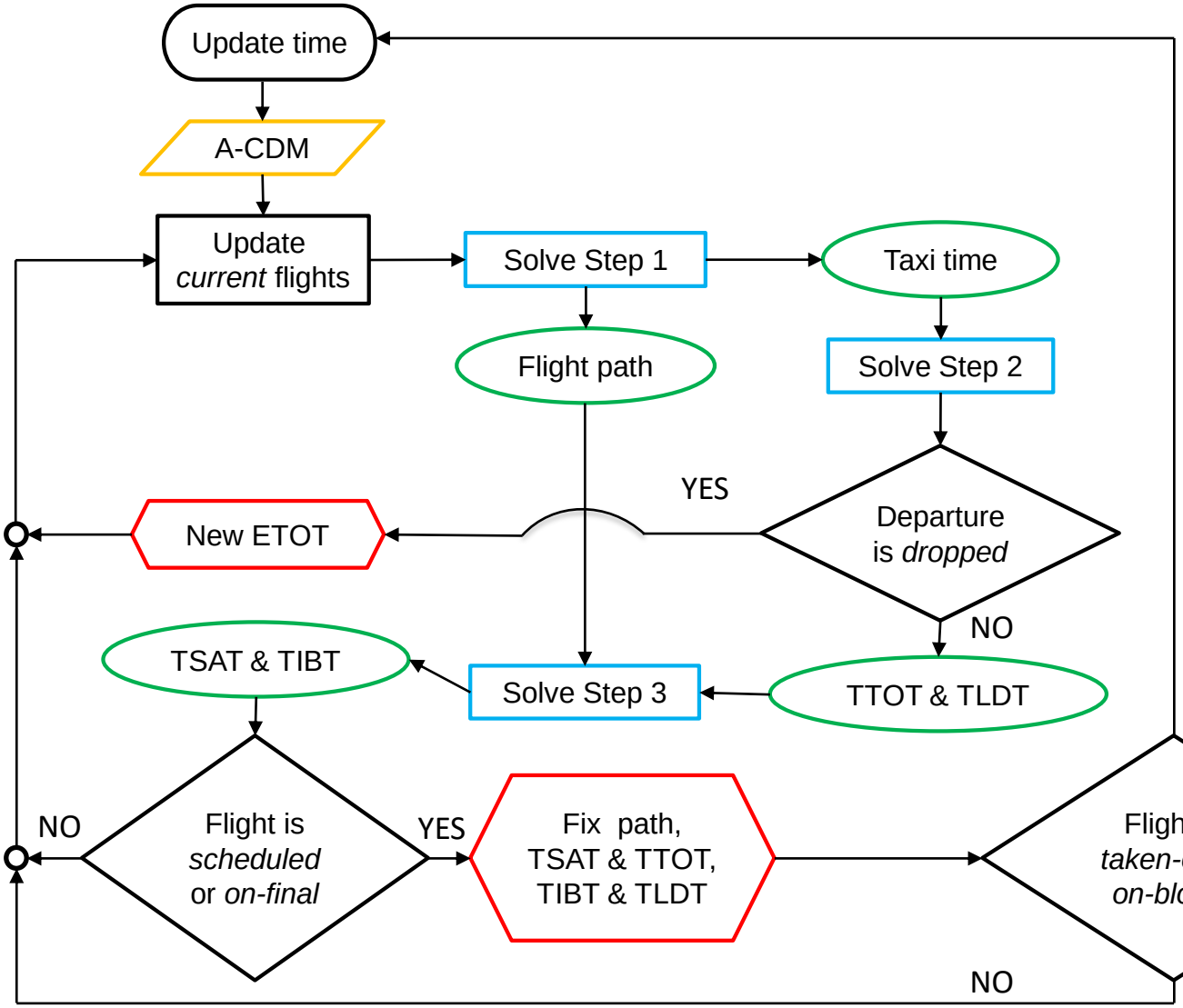
- assign a schedule time to arcs and nodes of shortest paths computed at Step 1;
- satisfy the order of arrivals and departures on the runway established at Step 2;
- satisfy all precedence and separation constraints (job-shop scheduling problem).

Modelling: Mixed Integer Linear Programming (MILP) problem

$$\min \sum_{l \in L} \left(t_l^{g_{in}(l)} - t_l^{RWY} \right) + \sum_{d \in D} \left(t_d^{RWY} - t_d^{g_{out}(d)} \right)$$

TIBT TLDT TTOT TSAT

Global algorithm flow



- Current: SOBT - 40'
  SIBT - 40'
- Dropped: shifted of 10'
- Scheduled: TSAT - 15'
- On-final: TLDT - 15'
- Taken-off: TTOT + 10'
- On-blocks: TIBT + 10'

Differences from baseline formulation

Present paper work is inspired by **Kjenstad et Al.** studies (2016):

- Heuristic decomposition of the integrated problem DMAN+SMAN+AMAN.
- Applied to Hamburg (two runways) and Arlanda airports (three runways).

Major differences and original contributions:

- Linate context is pretty different (single runway and single main taxiway);
- Step 1: based on "line graph model" → Used simplest "maximum flow model";
- Step 1: not guarantee of full resources exploitation → Added term in obj. function;
- Step 2: flights with CTOT assigned can be dropped → Forced to depart;
- Step 2: no re-scheduling of dropped flights → Added re-iteration;
- General: not fixing optimal values → Changed.

Description of the two case-study days

8th November 2016 (Tuesday):

- **no ice or snow** conditions;
- **no traffic congestion** problems;
- total flights: **314** (almost 50% departures and 50% arrivals);
- 34 general and business aviation flights;
- 56% of flights operated by **Alitalia** (A319, A320, E170, E190).

15th February 2017 (Wednesday):

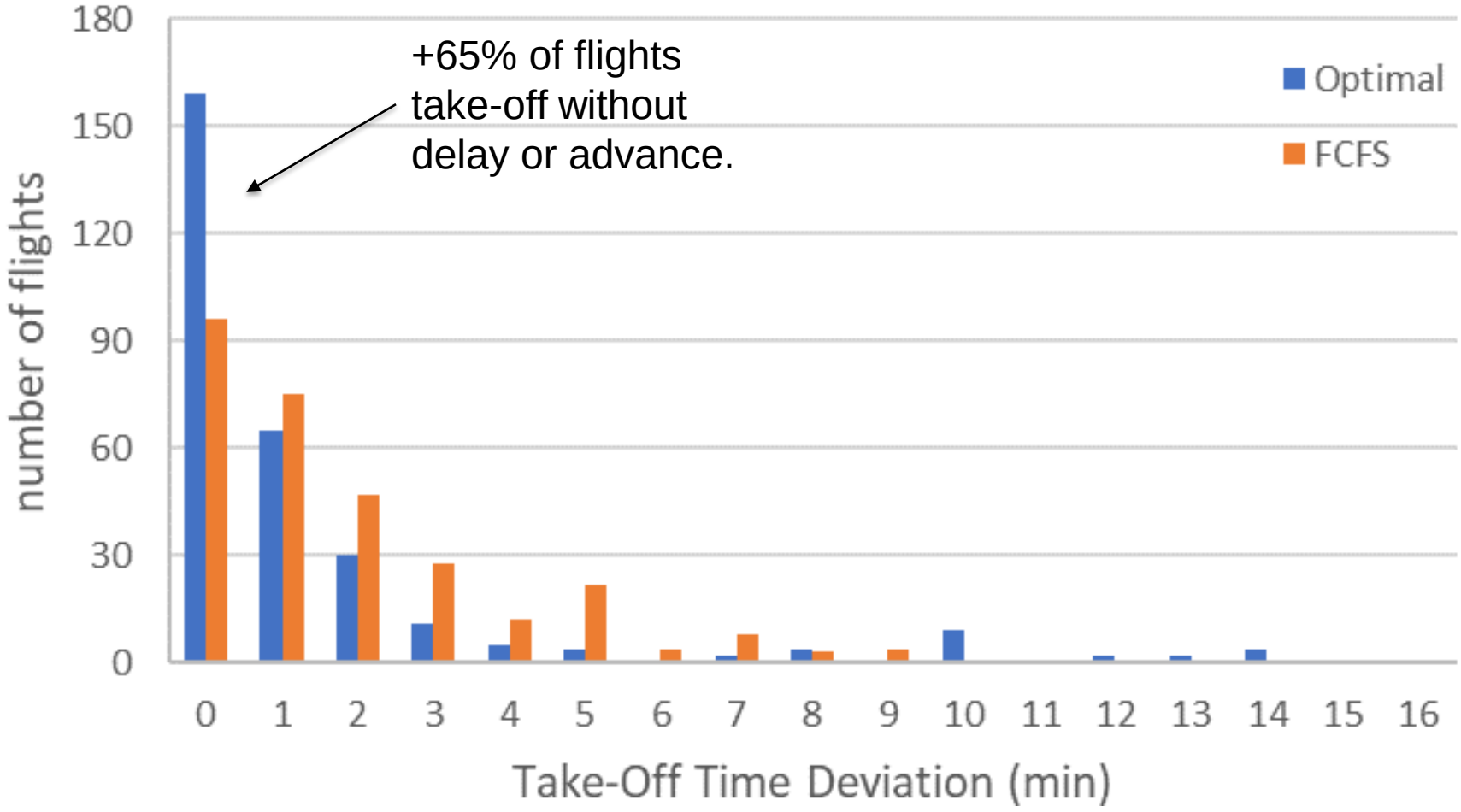
- **ice condition** (9 aircraft underwent de-icing procedures);
- **no traffic congestion** problems;
- total flights: 328 (almost 50% departures and 50% arrivals);
- total flights analysed: **328-9 = 319**;
- 37 private flights (general and business aviation);
- 53% of flights operated by **Alitalia** (A319, A320, E170, E190).

Results analysis

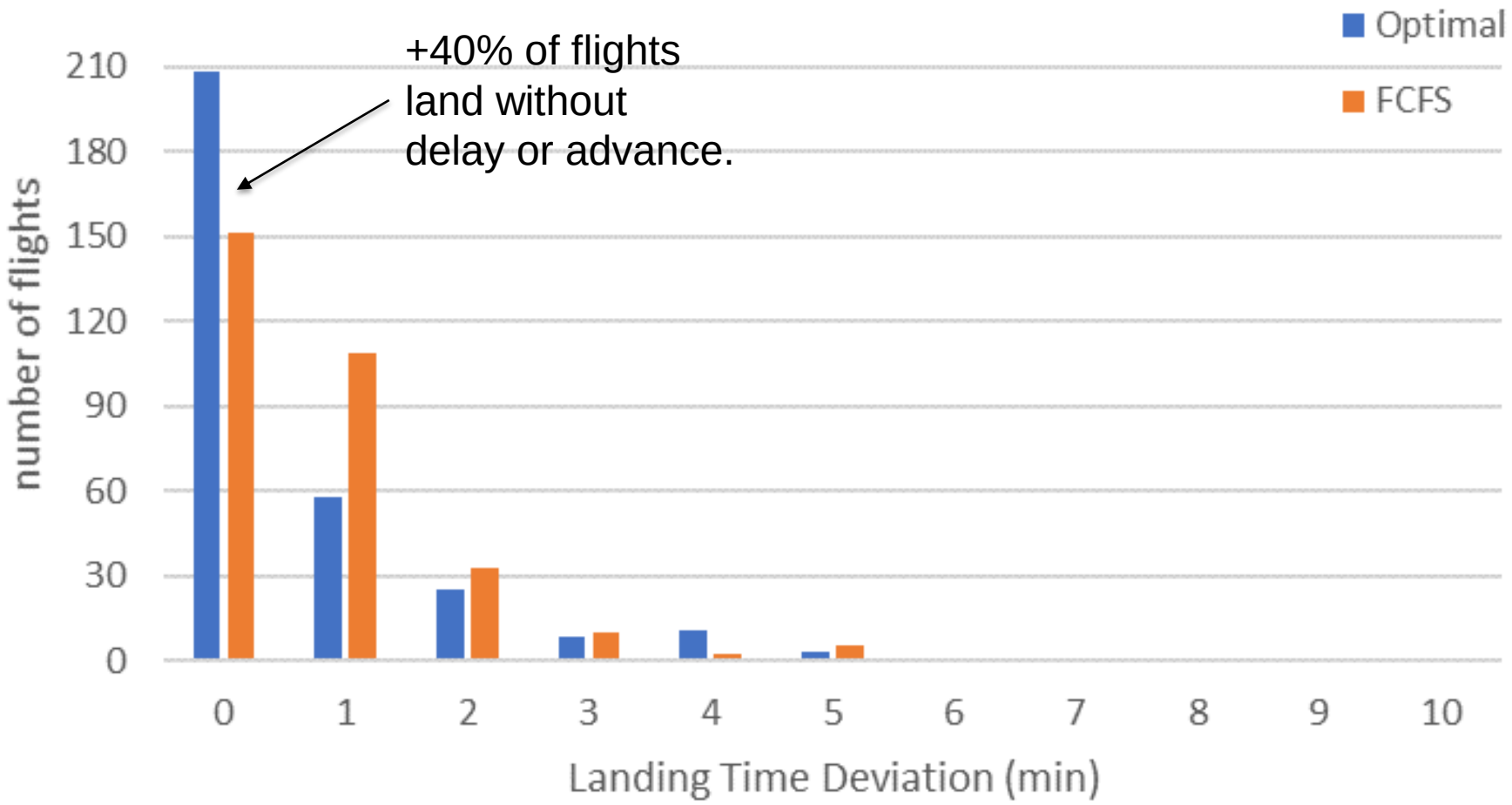
Day	Type	Time Deviation	Taxi time	Fuel consumption
8/11/2016	Arrivals	-26% (-30")	-4% (-10")	-4% (-300 kg)
	Departures	-0% (/)	-10% (-1' 8")	-7% (-1.6 ton)
	All flights	-11% (-30")	-8% (-1' 18")	-6% (-2 ton)
15/2/2017	Arrivals	-37% (-37")	-9% (-36")	-23% (-1.8 ton)
	Departures	-13% (-36")	-18% (-2')	-16% (-3.9 ton)
	All flights	-23% (-1' 13")	-16% (-2' 36")	-18% (-5.6 ton)

- The algorithm works, in the worst case, as well as Air Traffic Controllers: **more punctuality**.
- Reduction in taxi time yields **less noise, reduced fuel consumption, increased smoothness** and **safety**.
- Reduction in fuel consumption guarantees **lower CO_2** emission (approx. 13 football fields of forest) and **savings** (approx. 4 k€ in the two days; 2 k€ only by Alitalia).
- Heuristic decomposition guarantees low computational time (< 0.1s per Step), so **high dynamicity**.

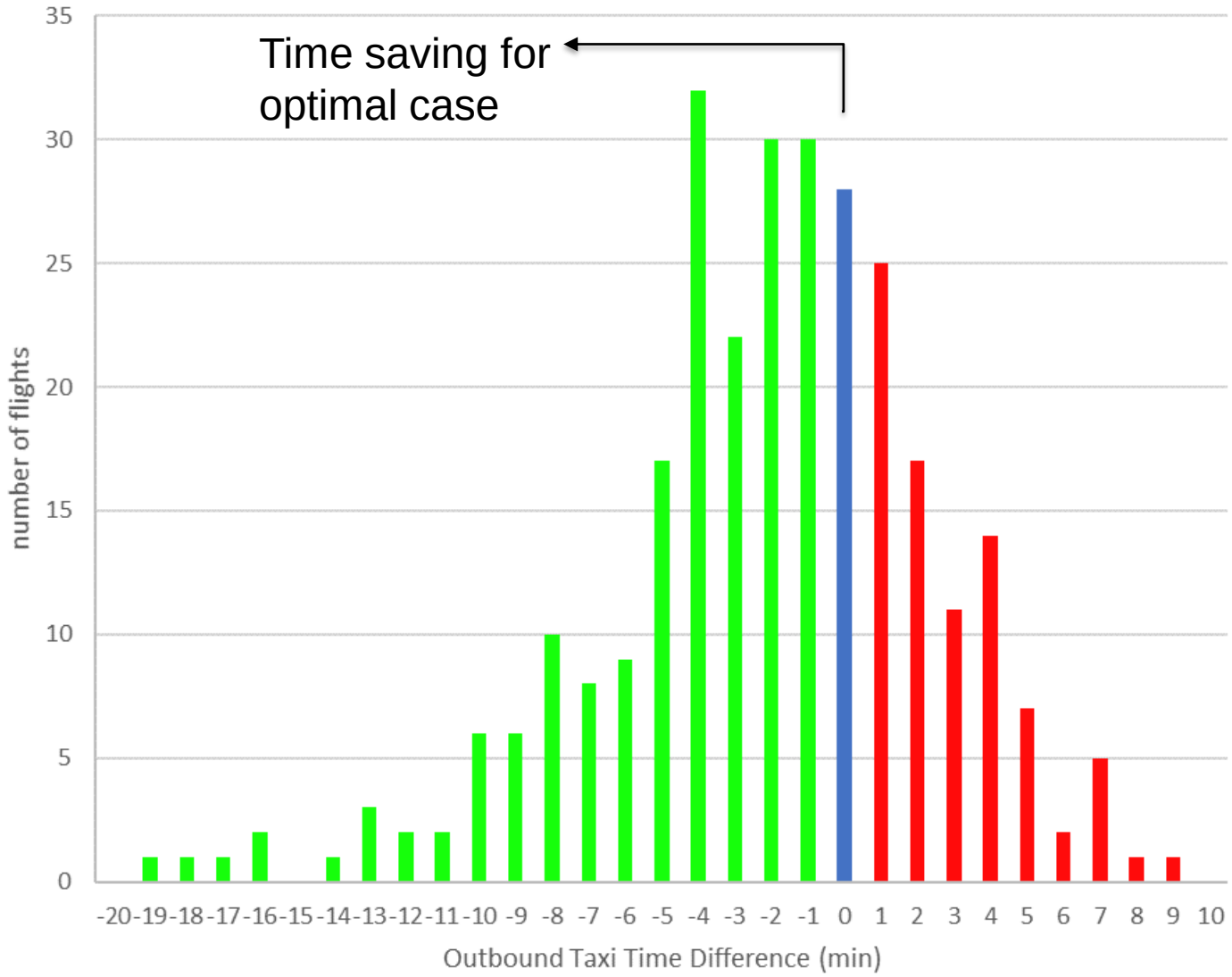
Take-Off Time Deviation for both case-study days



Landing Time Deviation for both case-study days



Outbound Taxi Time Difference for both days



Conclusions and future developments

- Following EU directives and using specific tools of the Operational Research, **the designed algorithm showed that it is possible to improve Air Traffic Management at Linate airport** with an integrated approach DMAN+SMAN+AMAN.
- The comparison of computational results with what actually happened in two case-study days showed that the algorithm can potentially help airport stakeholders in **reducing mean time deviation, taxi time and fuel consumption.**

- **Further analysis are needed**, comparing performance with additional days that include different operative conditions, and possibly testing the algorithm in a real-time environment.
- **Future developments** may comprise:
    - dynamic calculation of the delay along the taxiways;
    - implementation of the "De-icing management tool";
    - implement some algorithm for help ATC to respect computed TLDT;
    - apply the algorithm to other airports (e.g. Milano Malpensa).

Thank you for your attention

References

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2. D. Kyenstad, C. Mannino, T.E. Nordlander, P. Schittekat, and M. Smedsrud. "**Optimizing AMAN-SMAN-DMAN at Hamburg and Arlanda airport**". In: Proceedings of the Third Innovation Days, 26th -28th November *2013*. Ed. by SESAR. 2013.
3. G. Pavese. **An integrated solution for the optimization of the departures, surface and arrivals management at Milano Linate airport**. MSc Thesis. Politecnico di Milano. https://www.politesi.polimi.it/handle/10589/134016