OptiFrame Framework

The OptiFrame Consortium

Lancaster University

CFR CONSORZIO FUTURO IN RICERCA

nlr

EUROCONTROL

Brussels, February 14th 2018

SESAR JOINT UNDERTAKING

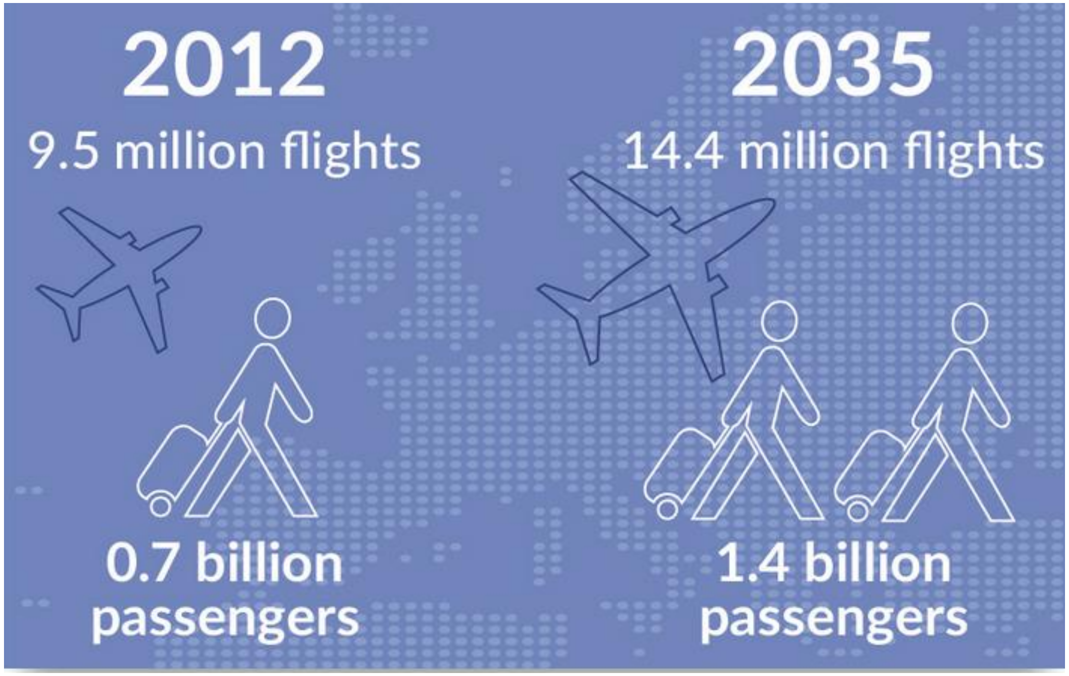
Objectives of the presentation

- An optimisation framework for TBO which assigns 4D-trajectories to flights based on the stakeholders' preferences and priorities.

Table of content

1. Problem context

1. Problem context (1/3)



Source ATM MasterPlan

- To ensure the sustainability and competitiveness of aviation in Europe, a clear vision on how to deliver a high-performing ATM system has been set up: **European ATM Master Plan.**
- The Trajectory Based Operations (TBO) concept is identified as one of the cornerstones of the future ATM system.

1. Problem context (2/3)

The **Global ATM Operational Concept** describes TBO as follows:

"Air traffic management (ATM) considers the trajectory of a manned or unmanned vehicle during all phases of flight and manages the interaction of that trajectory with other trajectories or hazards to achieve the ***optimum system outcome, with minimal deviation from the user-requested flight trajectory, whenever possible****."* (International Civil Aviation Organization-ICAO (2005), Global air traffic management operational concept. First edition-2005.)

1. Problem context (3/3)

- The TBO concept creates an environment for **information sharing** and **collaborative decision making** between the ATM **stakeholders.**

- The development and implementation of the TBO concept requires the development of **optimization models and algorithms.**

- This will allow pertinent decision makers and stakeholders to examine the trade-off between users and system optimum trajectories and to **facilitate the definition of commonly accepted trajectories by all stakeholders.**

2. OptiFrame approach

2. OptiFrame approach (1/3)

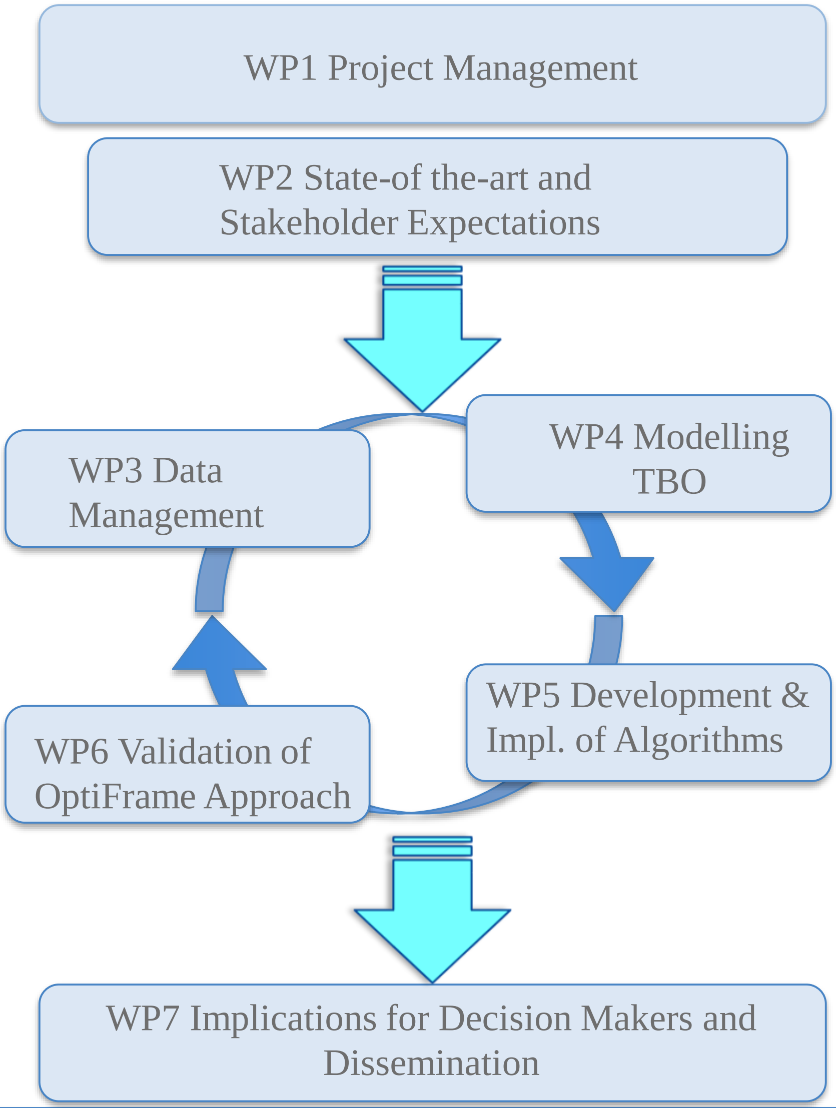
Objectives

Application of principles of mathematical modelling and optimization to **configure and assess the performance of the Trajectory Based Operations (TBO) concept.**

- ✈Viability of the concept
- ✈Major issues (e.g., barriers, constraints, stakeholders' expectations, etc.)
- ✈Whether and to what extent the objectives of flexibility and predictability of the ATM system can be achieved

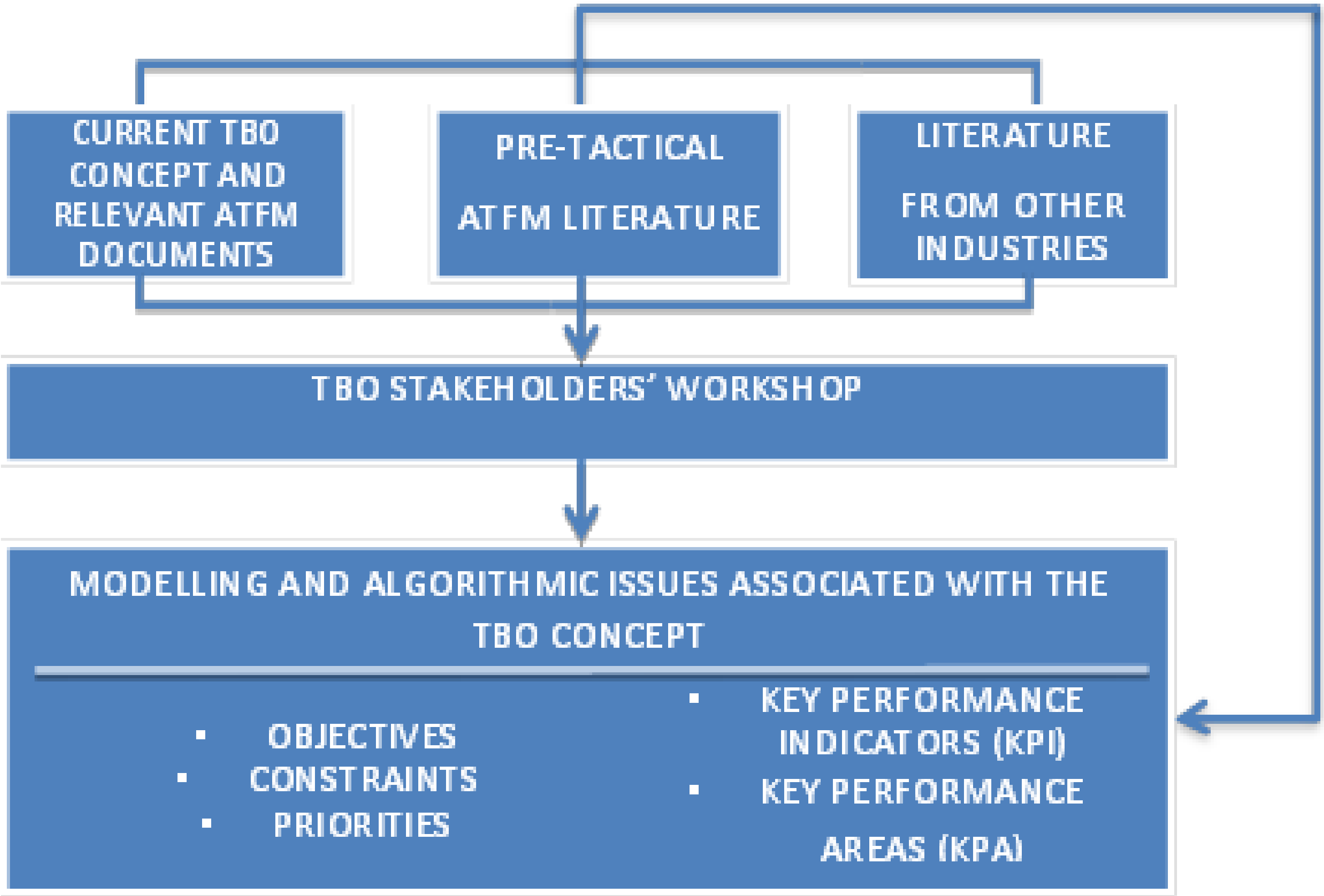
2. OptiFrame approach (2/3)

Project structure



2. OptiFrame approach (3/3)

Methodology



3. Stakeholders' expectations

3. Stakeholders’ Expectations (1/3)

Preferences

- ✓ Time deviation (departure delay)
- ✓ Horizontal deviation
- ✓ Vertical deviation

Priorities

OptiFrame model incorporates the three prioritization mechanisms proposed for step 2 of User Driven Prioritization Process (**Fleet Delay Re-ordering, Selective Flight Protection & Margins**) by Eurocontrol. (SESAR, D07 UDPP Step 2 V1, Project 07.06.04)

3. Stakeholders' Expectations (2/3)

OptiFrame SESAR JOINT UNDERTAKING

KPAs & KPIs

- Cost effectiveness
- Fuel efficiency
- Predictability
- Flexibility
- Punctuality
- Equity & Fairness

- Fuel costs, time costs, ATC costs
- Average fuel burnt per phase of flight
- Dep/Arr close to scheduled times
- User preferred routes
- Delay
- Equal access to airspace services

3. Stakeholders’ Expectations (3/3)

Requirements of TBO

- Consider the stakeholders’ **preferences**
- Consider the stakeholders’ **priorities**
- Produce efficient **4D-trajectories**
- Facilitate trajectory negotiation and coordination
- The optimization modelling should consider **individual flights** and should be holistic in terms of assessing the resulting impacts.

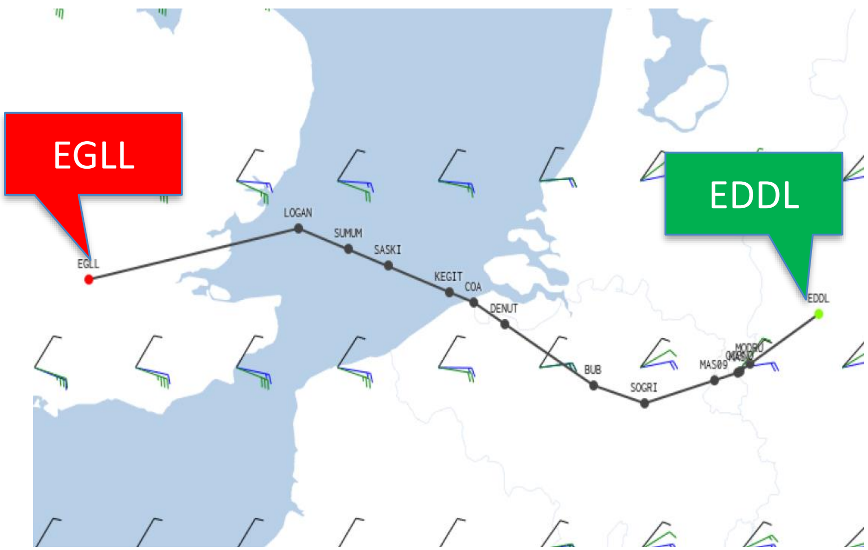
4. Modelling Approach

4. Modelling Approach (1/6)

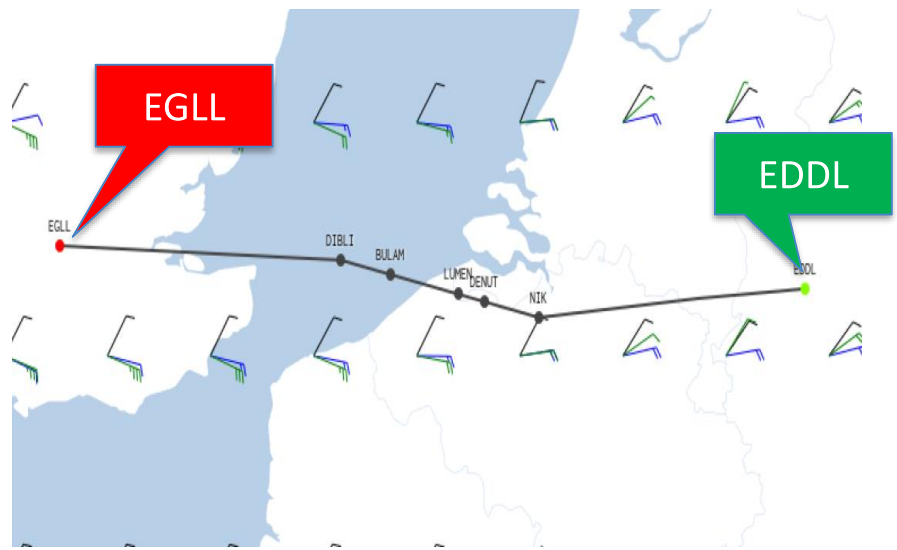
Flight trajectories and OptiFrame model:

- The OptiFrame model assign a 4D-trajectory to each flight.
- A 4D-trajectory gives the position of the flight in terms of arc and altitude being flown for each time period.

User preferred trajectory



Output trajectory



4. Modelling Approach (2/6)

OptiFrame SESAR JOINT UNDERTAKING

Stakeholders' preferences and OptiFrame model:

AUs express their preferences in terms of time deviation, lateral deviation & vertical deviations

+

Stakeholders identified KPIs that may reflect costs related to:

1) Delay

2) Flight efficiency

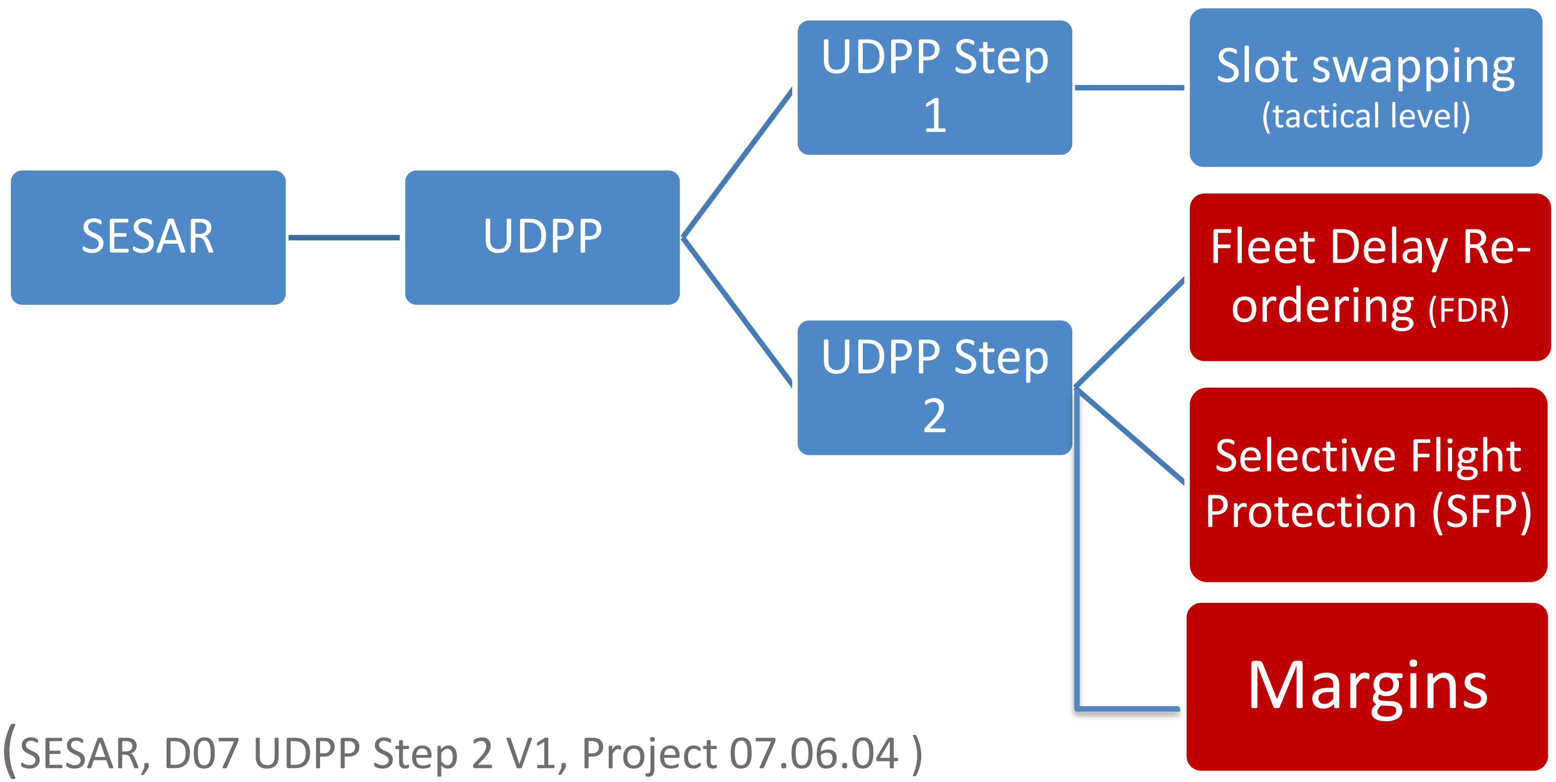
3) ANS route charges

Availability of cost data information ?

Multi-objective optimisation models

4. Modelling Approach (3/6)

Prioritization within SESAR:



(SESAR, D07 UDPP Step 2 V1, Project 07.06.04)

4. Modelling Approach (4/6)

Airspace users' priorities (SESAR, D07 UDPP Step 2 V1, Project 07.06.04)

Fleet Delay Re-ordering (FDR) mechanism:

AUs assign priority values:

- From 1 (highest priority) to 999 (lowest priority)
- "B": the flight should keep the baseline delay
- "S": the flight is a candidate for cancellation or re-routing

Selective Flight Protection (SFP) mechanism:

- AU can protect or suspend flights according to their priorities

Margins mechanism:

- "time not before" rule or/and a "time not after" rule.

4. Modelling Approach (5/6)

The constraints:

- Single trajectory constraints: make sure that each flight is assigned a unique 4D-trajectory.
- Airport capacity constraints: ensure that airports departure and arrival capacities are not exceeded
- En-route sector capacity constraints: ensure that en-route sectors capacities are not exceeded

4. Modelling Approach (6/6)

Summary of the optimisation model:

Minimise $\begin{cases} Total\ delay \\ Total\ deviation \\ ANS\ route\ charges \end{cases}$

s.t.

1. Single trajectory constraints
2. Airports' departure and Arrival capacity constraints
3. En-route sectors capacity constraints

5. Solving the OptiFrame model

5. Solving the OptiFrame model

- We developed an exact branch-and-cut algorithm that uses a commercial solvers (*IBM CPLEX*) to solve the optimization model
- This solves the problem with **accuracy**, but the running time is **too long for large instances**
- We developed a **heuristic algorithm**, which **approximates the solution**
- The heuristic **reduces considerably the computational time** and provides a **good approximation** of the exact solutions

OptiFrame Framework

Thank you very much for your attention!

This project has received funding from the SESAR Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No [number]

SESAR
JOINT UNDERTAKING

Founding Members
EUROPEAN UNION EUROCONTROL