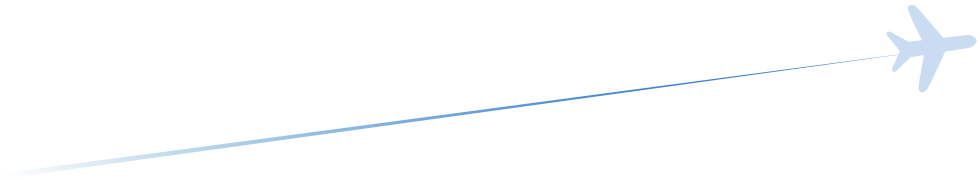

D6.3 Workshop results summary

Deliverable 6.3

Domino

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Authors of the document

Name/Beneficiary	Position/Title	Date
Luis Delgado / University of Westminster	Project member	27 June 2019
Gérald Gurtner / University of Westminster	Project member	27 June 2019
Andrew Cook / University of Westminster	Project coordinator	27 June 2019

Reviewers internal to the project

Name/Beneficiary	Position/Title	Date
Graham Tanner / University of Westminster	Project member	28 June 2019

Approved for submission to the SJU By — Representatives of beneficiaries involved in the project

Name/Beneficiary	Position/Title	Date
Andrew Cook / University of Westminster	Project coordinator	28 June 2019

Rejected By - Representatives of beneficiaries involved in the project

Name/Beneficiary	Position/Title	Date
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Domino

NOVEL TOOLS TO EVALUATE ATM SYSTEMS COUPLING UNDER FUTURE DEPLOYMENT SCENARIOS

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Abstract

This deliverable summarises two workshop activities carried out with stakeholders to provide feedback on the modelling, metrics and first results of Domino. How the feedback will be used in the project is highlighted.

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Executive summary

Two separate workshop activities were performed in order to gather feedback on Domino's model, metrics and first results on the investigative case studies.

The first interaction was focused on airspace users and carried out at the EUROCONTROL Experimental Centre on 7th May 2019. It involved ATM experts from EUROCONTROL and 7 airlines. This was followed up with a dedicated meeting at the University of Westminster with a representative from the NM Aircraft Operator Liaison Cell (16th May 2019) to gather further information on airspace users' behaviour.

A dedicated workshop was organised by Domino at the SJU premises in Brussels on 4th June 2019. This workshop was targeted at ATM and modelling experts. Besides the current model capabilities and results, Domino obtained feedback on the potential future evolution of the project as a tool and from a metrics perspective.

The feedback obtained in the above-mentioned sessions will be used to modify the model, the scenarios and the metrics for the final development of the project.

The detailed evolution of these aspects will be reported in D3.3 (Adaptive case studies description) and the final results of Domino will be reported in D5.3 (Final tool and model description and case studies results).

1 Introduction

After the first version of the model had been implemented (following the description presented in D4.1. Initial model design) and first results obtained for the investigative case studies (D3.2 Investigative case studies description, D5.2 Investigative case studies results), two workshop activities were carried out to obtain feedback for Domino. These two workshops were targeted at different audiences with different objectives:

- **Airspace users' workshop**: Domino had a dedicated session within a UDPP workshop organised by EUROCONTROL at the EUROCONTROL Experimental Centre in Brétigny on 7th May 2019. The main objective for Domino in the workshop was to present to airspace users the different assumptions of the model in order to validate them (particularly the airline operating centre and flight agents' behaviours). Preliminary results and the modelling approach were also presented in order to obtain feedback from Airspace Users and from ATM Network experts. A follow up meeting with the NM Aircraft Operator Liaison Cell was carried out at the University of Westminster (16th May 2019) allowed us to increase our insight into the airline's behaviour and the feedback received on 7th May 2019.

- **Experts' workshop**: A dedicated workshop organised by Domino was carried out at the SJU premises in Brussels on 4th June 2019. This was a full day workshop. The target audience were ATM and modelling experts. Besides presenting the model, its assumptions and Domino's approach, the first results from the investigative case studies were shared. The objective of this workshop was to obtain feedback on the model in order to apply suggested modifications for its final version. The workshop also aimed at obtaining feedback on the investigative case studies results in order to help us identifying the adaptive case studies and their prioritisation. Feedback was also obtained on the metrics computed and on their future possible evolution.

This deliverable presents a summary of the activities performed on these different activities, the feedback obtained and how this will be considered in Domino during the final phase of the project. **The detailed modifications made to the model, metrics and scenarios will be captured in D3.3** (Adaptive case studies description).

1.1 Deliverable structure and contents

The document is structured in the following way: first for each workshop, a description of the activities carried out, audience and feedback obtained is presented. Then, the considerations for the Domino model, metrics and case studies are described. Finally, the deliverable closes with the next steps and look ahead.

2 Airspace Users' Workshop

2.1 Summary

This workshop was organised by EUROCONTROL on 7th of May 2019. The workshop was on UDPP and Domino had a dedicated session to present the project and to discuss with airspace users. Some of EUROCONTROL's ATM experts attended in a first part which was devoted to present Domino's objectives, methodology, approach and model. A follow up session was held with a representative from the NM Aircraft Operator Liaison Cell at the University of Westminster on 16th May 2019.

Feedback was obtained on the modelling assumptions for the airspace user's behaviour and on the metrics and modelling approach from the ATM experts.

2.2 Targeted audience

The targeted audience were the airspace users (in particular, experts on airline operations) and ATM experts from EUROCONTROL.

2.3 Workshop objectives

The main objectives of the workshop were to obtain feedback on the:

1. model, methodology and metrics from ATM experts,
2. modelling assumptions for airspace users' processes,
3. applicability of Domino on different tasks required by experts and airspace users.

2.4 Workshop organisation

The workshop was organised into two sessions: Domino's overview (objectives, methodology, approach and modelling), and dedicated airspace users' questions.

2.4.1 Part 1: Domino's overview

This part was an hour duration with a presentation from the Domino's members of the consortium including high-level questions on the project. Domino's objectives, methodology, approach were presented. The modelling approach was described followed by the detail of the three mechanisms considered and the definition of selected investigative case studies. First preliminary results were presented focusing on the capabilities to generate passenger metrics.

The modelling approach and the first results were discussed with the attendees.

2.4.2 Part 2: Dedicated airspace users' questions

Specific questions on the airspace users' assumptions and processes carried out in Domino were discussed with the airspace users. These questions were divided between Information and flight planning, and tactical decision-making choices.

The specific questions included:

- Under which conditions would you resubmit an initial flight plan?
- What would trigger a full flight plan trajectory modification to avoid an ATFM regulation?
- When are EOBT and EIBT updated? Do they trigger downstream re-computations?
- Are there fixed criteria for triggering a reassessment of the flight plan / route selected?
- From the first rotation, what is the split between AUs that: a) 'curfew' costs and/or pax-related costs are explicitly quantified; b) 'rules of thumb' predominate?
- What is the maximum number of times a decision on delay recovery might be reviewed for an intra-ECAC flight? What pilot autonomy exits?
- Under what circumstances does a flight wait for passengers? Who makes the decision and based on what information? What is the local / dispatcher autonomy?
- Under what circumstances is fuel conservation given a priority?
- What type of post analysis is carried out? Does this quantitatively or qualitatively feed the next schedule-planning phase?

The follow-up session with the NM Aircraft Operator Liaison Cell allowed us to expand on some of these questions.

2.5 Attendance

For the first part, besides the airspace users, the presentation was attended by 10 EUROCONTROL ATM experts.

For the second part, the 7 airlines which attended the first part, with a mix of regional, low cost and full carriers were represented.

2.6 Feedback

The capabilities of the model to represent passenger metrics and the detail of the agents' capabilities and interactions were well received by the audience.

The specific feedback obtained can be grouped in two categories as presented below:

2.6.1 Flight planning processes

The airspace users indicated that a first flight plan is usually submitted between 10-16 hours before SOBT (even larger periods in some time). However, as information is available (e.g., better weather forecast, conditional routes availability) updates are common. To avoid a late submission, flight plans are sent just before the 3 hours before EOBT threshold.

In some cases, as a reaction to disruption, a completely new flight plan (which might even include a new route) could be submitted up to 30 minutes before EOBT.

Most airspace users operate a two-crew (two-shift) day.

2.6.2 Delay management

Pre-tactical delay management (flight plan resubmitting, aircraft swap and cancellations)

When managing delayed flights parameters not currently considered in Domino can play an important role: crew (e.g., number of hours available) and maintenance checks (e.g., mandatory ramp checks or repositioning of aircraft at the end of the day to allow for larger maintenance processes. A-checks are carried out overnight and 2A-checks must be completed over two consecutive nights which might drive the management of disruption under consecutive days.

In general, airlines will focus on critical flights which have been identified prior operations (e.g., flights with high number of connecting passengers). These flights will be closely monitored.

For hub-based operators, the operations revolve around the long-haul connecting flight (working with waves). Therefore, disruption can be seen as impact of flights on these long-haul. For low cost point to point carriers, curfew at the end of the day might have a larger impact. For some airlines, rotations can be so tight that propagation of delay through the day might lead to curfew issues. Note that for curfew different airports might have different policies (a fee if curfew is missed or not able to operate).

The importance of buffers was confirmed by the participants as delays below 10 minutes are usually not actively managed but when delays increase over 20-25 minutes, they start to impact rotation of flights and a closer monitoring and intervention is done. The main goal of applying changes to planned operations is to stabilise rotations.

Aircraft swapping, performed in conjunction with cancellation, are a widely used tool to generate buffers and fix the ‘end of the day’ operations. This helps to ensure that curfews are respected, crew is maintained below their operating hours and aircraft finish at the adequate airport when maintenance is programmed. Aircraft swap might be considered once costs of delay are expected to rise (e.g., passengers being affected by Regulation 261 compensation).

Depending on the complexity of the airline operations focus might shift from specific estimation of costs to minimise high disruption and maintain adherence to schedules without explicitly considering costs.

In case of heavy ATFM delay (e.g., during a strike), some airspace users might accept a large ATFM delay while hoping other airlines might refile/cancel and obtain a significant improvement.

Tactical delay management (cost index adjustment and actively delaying flights)

Once the aircraft is airborne (around 15 minutes after take-off) the EIBT for that flight is computed. This will already be used to update status of next rotation (e.g., considering if doing an aircraft swap in the next rotation). Usually, this is reassessed around 30 minutes before landing. Some airlines will propagate this information for all the flights during the day, while others would focus only on the next rotation. EOBT of the next rotation would usually not be updated until the previous flight is in the air.

Tactical delay recovery by adjusting cost index is limited on its potential. Airlines try to benefit from ATC flexibility (e.g., using directs). However, this is more an opportunistic approach. All airlines agreed that pilot autonomy is limited and the tendency is towards higher centralised decision (focused on delay and/or costs).

Actively delaying outbound flights for waiting for passengers is a common practice but considering expected cost and focused on long-haul flights. This can be done in waiting block times (e.g., 10 minutes) or as a more manual intervention by dispatchers.

Passengers disruption management

Airlines which are integrated in an alliance will consider the re-routing of passengers who have missed their itineraries on the whole network, including different hub than the one planned by the passenger.

In some cases, early rebooking (including earlier than planned) could be considered. The importance of shuttle service (operated with spare capacity) in critical origin-destination pairs was highlighted during the workshop. When managing inbound flights with connecting passengers, minimum connecting times and passengers' buffers to do the connections are considered.

Finally, some hubs are operated so close to their capacity that a severe disruption with passengers missing connection might require several days to solve rebooking passengers on further on-going flights.

NB. Airline-specific information has been withheld from this report, for reasons of confidentiality, but have been used by the team in respect of modelling refinement considerations.

3 Experts' Workshop

3.1 Summary

A dedicated full day workshop was organised at the SESAR SJU offices in Brussels on 4th June 2019 with ATM experts. During the workshop Domino's model and first results were shared. The workshop focused on obtaining feedback to improve some of the modelling assumptions, but it particularly aimed at obtaining feedback on Domino's metrics and the potential evolution of the Domino's model, techniques and metrics in future research. This workshop was complementary to that described in Section 2, and did not include airspace users.

3.2 Targeted audience

The targeted audience were ATM experts.

3.3 Workshop objectives

The main objectives of the workshop were to:

1. increase the dissemination of the project among ATM experts,
2. obtain feedback on some of the modelling assumptions,
3. share and discuss the first results obtained by the model,
4. discuss what new metrics should be considered by Domino and the usability of the current ones,
5. consider the possible evolution of the model.

3.4 Workshop organisation

The workshop was organised in 5 sessions:

1. Domino project presentation
    a. Introduction to Domino project
    b. Model overview
    c. Model details: behaviour of the ABM model's agents
    d. Metrics design and logic
2. Initial results

3. Potential usage of Domino
4. Metrics and their evolution
5. Next steps

The objectives of each session were as follows:

- Session 1 presented the project, the model and the metrics that are defined in Domino. The objective of the session was to give a good understanding of Domino to the audience.
- Session 2 shared some of the first results obtained by the model and analysed using Domino's classical and network metrics (centrality and causality). This session objective was to gather feedback on the type of results that were already generated and to present the capabilities of the model.
- Session 3 focused on the potential applicability of Domino considering four different stakeholders' perspective: ANSPs, Passengers, Airports and Network Manager. Note that airspace user's feedback was gathered in the previous workshop (see Section 2).
- Session 4 was targeted and metrics and their evolution, gathering feedback on the usability of current metrics and the identification of potential future metrics that could be developed in a platform such as Domino.
- Session 5 summarised the main findings for the day and the next steps in the project.

This is the agenda that was used during the day:

3.4.1 Agenda

Time	Session
1000-1030	1.a Introduction to Domino
1030-1050	1.b Model overview
1050-1110	1.c Model details: behavior of the agents
1110-1125	*Break*
1125-1155	1.d Metrics design and logic
1155-1245	2. Initial results
1245-1345	*Lunch*
1345-1445	3. Potential usage of Domino
1445-1500	*Break*
1500-1600	4. Metrics and their evolution
1600-1700	5. Summary and next steps

3.5 Attendance

In addition to SJU experts, a total of 9 experts attended the workshop.

3.6 Feedback

The feedback obtained during the day can be summarised in the following categories:

3.6.1 Potential evolution of Domino tool

Feedback was gathered on the potential evolution of Domino to answer specific questions for the different stakeholders:

Airport perspective

- To include door to door analysis if it is feasible to extend this model to door-to-door.
- Detect airline behaviour from data analysis.
- Consider processes within the airport for passengers: security, boarding time (which is a source of delay). I.e., increase the granularity of the processes modelled at the airport, landside.
- It could be beneficial to model airports in more detail on some of its parts (e.g., runway, terminal) this would help to improve the runway throughput and taxi operations, for example.
- Consider how airports can be disrupted in non-standard situations, e.g., use of drones.

Passengers perspective

- Consider the purpose of travel when assessing the impact of delay (e.g., business meeting which might be highly impacted by delay).
- Use Domino as a tool to assess impact of prioritising different type of passengers. Consider analysis of trade-offs between passengers types.
- Analyse impact of changes in regulation (e.g., reduce threshold of compensation in Regulation 261).
- Consider more data on the passenger actions (e.g., if bags have been checked in). This could have an impact on some of the airlines' actions (e.g., wait for passengers).

ANSP

- Expand the en-route phase to explicitly model and understand impact of (airport) delays to the en-route phase, and vice versa.

Network Manger

- Domino as a model is good but work should be done to consider how to convert it into a tool.
- Consider changes in the system beyond mechanism such as modified Regulation 261 to understand how the system adapts.
- To consider more explicit pre-tactical phase in order to assess impact of considering demand and flight plan submission.
- Testing different ways of assign delay in case of extreme delays, i.e., considering NM behaviour.
- Investigate benefits of early submission of flight plans (earlier than EOBT-3h), calculate cost-benefit to the airspace users.

3.6.2 Feedback on metrics evolution

Feedback was gathered on potential evolution of Domino's metrics considering the needs of the different stakeholders:

Airport perspective

- Capture missed connections in relation to connecting time. Analyse the impact of allowing connections for low cost carriers (such as 'GatwickConnects' solutions).
- Produce metrics on minimum connecting times (MCT) and dwell times, and how they impact revenue.
- Expand metrics to the door-to-door context.
- Consider airport ranking based on causality, centrality metrics, vulnerability for delay propagation.
- Focus on how to assign delay to reason as processes (which might have some delay) could run in parallel.
- Consider causality metrics to capture interaction among airlines at airports. I.e., metrics to capture how delays of one airline affects another. This could be relevant for airports dominated by a given airline.
- Produce airport capacity curves based on point when the system becomes unstable to derive airport capacities.
- Consider queue sizes at arrival and departure.

Passengers perspective

- Develop specific metrics to capture market segmentation (type of passengers and of itineraries (direct, with connections). Consider for example the passenger delay weighted by the number of passengers in different categories (basic ticket, flex ticket, business passenger, etc.).
- Provide distributions of connecting times (planned and executed).
- Capture passenger utility (using passenger fares as proxy).
- Consider passengers segmentation to provide information on the metrics in order to analyse trade-offs among passengers types.
- Analyse which origin-destination pair allow business trips on the day to assess competence with other means of transport (e.g., rail).
- Normalise cost for passenger by number of kilometres flown.
- Estimate relative importance of legs on multi-leg itineraries on total passenger delay (i.e., capture importance of first legs delays on potential missed connections).
- Passenger metrics and tail/causality metrics were proving useful, but they need to improve / substantiate regarding the monetisation of certain non-classical metrics and explicitly state their added value (investigate relationship between tail metrics and classical variances); and an increased cover regarding passenger utility would be useful.

ANSP

- Focus on KPIs as defined in the Master Plan and the Performance Framework.
- Consider re-routings and metrics to capture their impact.
- Relationship between delay and cost of delay at ANSP level.

Network Manger

- Monitor deviation from schedules (cancellation rates).
- Capture traffic complexity/workload approximation airborne by computing dynamic hotspots (e.g., number of flights in a cell of an airspace grid).
- Instead of focusing on delay focus on capacity available. Nowadays focus is on delay, which is a proxy to lack of capacity, but capacity itself (as a resource) is not well modelled/captured. Currently, the NM is managing lack of capacity instead of capacity.
- Work towards metric consolidation. It might be worth it to have less metrics but better integrated.
- Capture the benefit of early flight plan submission (e.g., predictability).

- Focus on the trade-off between delay and flight efficiency.
- Explore the trade-off between AU accepting more delay, c.f. parallel improvement in flight efficiency.
- Relationship between delay and cost of delay at Network level.

3.6.3 Other feedback

Besides input on the model and the metrics and its possible evolution, Domino gathered feedback on further issues such as:

- In future reporting, the Domino team should more clearly describe the state of the art re. modelling in this area, where Domino is positioned, and the value we are hoping to add.
- The stressed cases in the model were not behaving quite as expected. One possible explanation is that the stress was too high, and the mechanisms were not managing the delays.

With respect to the centrality and causality metrics:

- It was considered that a link between causality and centrality metrics and cost is needed in order to allow their integration in cost benefit analysis.
- Further work is required on the usability of network metrics from an operational perspective.
- It was flagged that it could be interesting to compare those network metrics with the performance of other indicators (to assess what are they adding and/or how they are correlated with other better known parameters). It might be worth it to compare with other indicators such as standard deviation of other metrics. Finally, how to consider these indicators within the current working environment of existing KPIs.
- Centrality was considered of higher relevance for decision making than causality.

As wider inputs and comments:

- It was felt (by the invited experts) to be good timing for such a model (e.g., w.r.t. the future airspace architecture report):
    - reflect on how it could be matured towards a tool per se (by stakeholder types). For a faster adaptation into a tool, it was felt that the passenger part could be too advanced and producing results which are interesting but lacking applicability when there is still not a full understanding on current flight-centric metrics;
    - disseminate the value of the agency of ABM in design feedback, c.f. repeated simulations, allowing the capture of ABM emergence behaviours.

- The team welcomed an invitation by PJ19.04 to present the project's results to partners in November 2019 (at a corresponding consortium meeting).
- The idea was mooted to invite external experts (such as at this workshop) to the Domino close-out meeting.

4 Considerations for Domino

The changes that will be made in Domino (model, metrics and scenarios) considering the feedback from the workshops and input from the verification and validation carried out by the Domino team will be reported in D3.3 Adaptive case studies description. In this section, besides feedback that can be considered for the future evolution of the tool, the main highlights from the feedback obtained in the workshops and their consideration in Domino are summarised. The specific input that will be used in the project can be grouped in the following categories.

4.1 Considerations for the model

In general, the feedback obtained from the model confirms the main assumptions considered however, there are specific considerations that should be taken forward in the final version of the model. In particular:

- The early submission of flight plan (10-12 hours before SOBT) does not have an impact on the model as we are currently considering that the flight plan is submitted 3 hours before SOBT. As discussed by the experts, airlines tend to resubmit a flight plan 3 hours before SOBT and, the early submission is used for demand estimation. However, as Domino does not explicitly model regulations of CDB based on the demand, this does not affect the behaviour of the model.
- The resubmission of flight plans could be made, when expected cost/delay is high at any time before departure. The model already considers this, but it could be reviewed to allow these resubmissions.
- In some cases, the model might be too advanced (e.g., explicitly computing cost of delay when deciding different delay management options) when airlines might operate with less explicit considerations (e.g., based only on total delay expected). On the other hand, airlines manage the operations of the aircraft for the whole day considering explicitly all the rotations of the aircraft through the day and even considering the impact of actions on multi-day operations which is out of the scope of the model of Domino (e.g., maintenance checks that need to be done several consecutive days and impose where the aircraft should finish at the end of the day). The airline, hence, could consider actions such as aircraft swapping that are not modelled in Domino. The overall behaviour of the model is adequate, but some of the actions could be more explicitly considered.
- The model could consider tactical recovery of delay when expected inbound delay is higher than 20-25 minutes. The feedback received indicates that for delays lower than those, airlines tend to operate as planned.
- The re-computation of the EIBT and the potential impact on the next rotation could be considered at TOC (15 minutes after take-off).

- From a passenger point of view, at hubs, for specific routes, it could possibly be considered that a passenger might board an earlier flight if available.

4.2 Considerations for the metrics

The metrics estimated in Domino and presented in the workshops were received positively by the attendees. The feedback obtained will be considered in the project as follows:

- The applicability of the network metrics should be further explored. In particular, focus should be given to their potential monetisation and understanding of their representativeness. This implies analysing how these metrics relate to more classical metrics in order to provide some metrics consolidation. These network metrics could then be used for ATM systems (e.g., airport) ranking, such as centrality, causality or vulnerability for delay propagation.
- More detail could be provided for passenger metrics, in particular: considering the disaggregation of metrics per passenger type and the consideration of connecting times (with their distributions). The door-to-door analysis could be included.
- Some metrics could be normalised based on distance to facilitate inter-airline comparison (e.g., cost/delay per km flown).
- Information on system status by reporting on queue lengths could be interesting.
- Airspace could be considered at a basic level to provide some indication of demand (hot-spots) and revenues per ANSPs.

4.3 Considerations for the case studies

The results presented focused on the unitary case studies which computed the impact of each mechanism independently. These were considered sufficient to present the model capabilities. Focusing on the evolution of the scenarios and their prioritisation remarks were made on:

- Analysis of the relevance of the stressed cases. In some cases, the system could be over-stressed meaning that the mechanisms do not cope adequately. It might be worth exploring intermediate situations as the baseline might have too much capacity.
- Focus should be given to scenarios which present the model applicability. In this sense, specific case studies could be more relevant (e.g., the impact of solutions such as 'GatwickConnects' which allows inter-airlines passengers connectivity might be interesting to study the applicability of the new network metrics).

4.4 Other

In addition to the feedback that could be considered for future evolutions of Domino, it was stated that in the follow-up deliverables, more detail should be given to the description of the state of the art and where Domino is positioned. This will be considered for the final technical deliverable D5.3 (Final tool and model description and case studies results).

5 Next steps and look ahead

The results of the analysis of the investigative case studies will be reported in D5.2 (Investigative case studies results). Then the feedback obtained the different dissemination activities reported in this deliverable will be considered along with the analysis of the results and the verification and validation of the model to provide an analysis of the changes that will be made to the model, the metrics and the scenarios for the final version of Domino. These changes will be reported in D3.3 (Adaptive case studies description). Both deliverables are expected for July 2019.

The model will be modified until September 2019, when the final results will be produced and described in D5.3 (Final tool and model description and case studies results; due in October 2019).

6 References

Domino Consortium, 2018. D3.2 Investigative case studies description.

Domino Consortium, 2018. D4.1. Initial model design.

Domino Consortium, 2019. D5.2 Investigative case studies results, *forthcoming*.

7 Acronyms

ABM: Agent-based modelling

ATM: Air traffic management

ANSP: Air Navigation Service Provider

ATC: Air Traffic Control

ATFM: Air Traffic Flow Management

AU: Airspace User

CDB: Capacity Demand Balancing

ECAC: European Civil Aviation Conference

EIBT: Estimated In-Block Time

EOBT: Estimate Off-Block Time

H2020: Horizon 2020 research programme

MCT: Minimum connecting time

NM: Network Manager

SESAR: Single European Sky ATM Research

SJU: SESAR Joint Undertaking

SOBT: Scheduled Off-Block Time

TOC: Top Off Climb

UDPP: User-Driven Prioritisation Process

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