Use case Report for the Data Infrastructure for National Infrastructure project (DINI)

Project MARS

Modelling Aviation Resilience Scenarios

Project Team

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1. Use case Report

1.1 Background and Context

The project investigates mass diversion events in the UK aviation sector. Mass diversion events pose a major challenge to the UK aviation system as such occurrences significantly increase the workload of the air traffic control officers, who must quickly identify multiple suitable diversion airports. This process can be quite time-consuming, which could lead to several fuel emergencies, thereby compromising the stability of the aviation system. An important contributing factor is the insufficiency of spare capacity in the system, a consequence of high utilization of the major UK airports as highlighted by a 2017 study conducted by the Civil Aviation Authority (CAA). Recognizing the imperative to address the management of mass diversion events, the ODLG (Operations Directors Liaison Group), a consortium comprising major UK airlines, airports, the main air navigation service provider, the regulator, the government, and various other stakeholders, has prioritized this concern. The ODLG serves as a collaborative platform for these diverse stakeholders to address issues related to the UK aviation system's resilience.

The working group developed the first iteration of a mass diversion protocol in 2019, aimed at expediting the diversion process. The protocol incorporates a pool of pre-approved slots at various UK airports, designed to facilitate efficient response during such incidents. However, several slots were withdrawn amid the COVID-19 pandemic, and the progress to enhance the mass diversion protocol has stagnated due to resource and time constraints. The ODLG members, especially the CAA, DFT, and NATS are key stakeholders in this project.

1.2 Description of Activities

The initial phase of the project involved data collection. Open-source data was fused with information from industry reports to establish a comprehensive database including scheduled arrivals/departures, airport stand capabilities and diversion priorities. The developed dataset underwent verification through discussions with industry stakeholders. This information exchange was done via presentations at various forums and a project overview, which was sent out to multiple aviation stakeholders. An example of this briefing document is attached in 0Appendix A. After the data was pre-processed, a computational model of the UK airport network was developed. The algorithm was developed using directed graphs. During simulations, the diversion airports are identified by the diversion priorities, stand availability, distance to alternate airports, and contractual agreements. The diversion problem was approached as a multi-constrained and multi-objective optimisation problem, enabling a more nuanced and realistic representation of the complex scenarios. This model enabled the research team to simulate airport closures and the subsequent diversion of aircraft to alternate airports. The project investigated the diversion process, highlighting potential bottlenecks in the system and providing crucial information for the ODLG for the next iteration of the protocol. A documentation report will be prepared where the model inputs and outputs, requirements, and methodology will be documented. Additionally, test cases will be prepared for the purposes of the end user.

1.3 Benefits of Data Sharing

Achieving resilience across the UK aviation network requires multiple stakeholders working together to ensure the system can effectively manage disruptions. One crucial aspect in this effort has been identifying the remaining spare capacity within the system. The 2017 CAA report examined the runway utilization of the six major UK airports, but another key limiting factor in handling diversions is the availability of aircraft stands. Without comprehensive data on stand availability, assessing the network's ability to manage a mass diversion event is challenging. During a mass diversion event, multiple aircraft require alternative airports within a short time frame. Therefore, access to relevant data sets is essential to develop a clear picture of the system's ability to respond to an airport closure.

By analysing the spare airport stands across the network, we gain the ability to estimate the overall system capacity and evaluate how effectively the network could respond to a large-scale diversion scenario. In addition to stand availability, contractual agreements between airlines and potential diversion airports further influence operational flexibility.

We contacted the CAA but our investigation revealed that a contractual agreement matrix did not exist. Consequently, we constructed our own matrix using current and historical flight data to map out airline operations at various UK airports over the past five years. To validate our findings, we cross-checked this data with five major UK-based airlines. While an industry-verified matrix could be a future workstream under the ODLG activities, our discussions and validations confirm that the data we have compiled is sufficiently accurate for running realistic simulations. By leveraging these insights, stakeholders can anticipate potential constraints and refine contingency strategies, ultimately improving the UK aviation network's resilience to large-scale disruptions, which is in line with ODLG's priorities.

The ODLG can utilize our data set and software tool to conduct tabletop exercises and scenario planning, simulating the impact of a mass diversion event. Identifying potential bottlenecks throughout the day enables the industry to proactively discuss contingency measures and refine protocols to protect operational integrity when key infrastructure is constrained.

Additionally, during the project we engaged with an airline operating multiple long-haul aircraft arriving at a specific time of day. Their primary concern was the potential closure of their home airport and the associated challenge of securing alternative large aircraft stands at other UK airports. Our data and software tool allow them to simulate various scenarios, assessing alternative diversion options for their wide-body aircraft. By running these simulations, they can enhance their contingency planning, ensuring a more robust and responsive approach to potential disruptions.

1.4 Barriers for Data Sharing

Aviation is a highly competitive sector, where data sharing and achieving better shared situational awareness have consistently been key focus areas for the ODLG. However, these goals have historically faced significant challenges due to the commercial sensitivity of the data and legal complexities surrounding ownership. Airlines, airports and other stakeholders are often cautious about sharing proprietary information, potentially impacting their competitive position. Despite these barriers, past initiatives have demonstrated that collaboration is possible. A notable example is the first iteration of a mass diversion protocol in 2019, which proved that data-sharing efforts can be successful when stakeholders align their interests to enhance the resilience of the aviation system.

To navigate the challenges of conflicting interests and commercial sensitivity, this project was designed using publicly available data. Conducted by an independent research team in collaboration with key UK aviation stakeholders, the approach ensured neutrality while maintaining industry relevance. The latest version of the prototype was shared with over 80 representatives from ten UK aviation stakeholders on 24th February 2025. By leveraging open-source data and cross-checking findings with industry representatives, we developed a platform that enables mass diversion simulations and supports scenario planning.

As outlined in section 1.3, one way to refine these simulations further is for the ODLG to conduct a comprehensive review of remaining airport stand availability and compile an industry-driven contractual agreement matrix. This approach would provide a clearer understanding of diversion options and operational constraints.

To support continued development and accessibility, we will upload the algorithm to the National Infrastructure Database along with an example dataset. The open-source approach enables organizations to use the tool for their own business continuity planning while allowing researchers to refine the algorithm further.

1.5 Sources of data – table

Data Source	**Data Description**	**Purpose**	**Technical Details**	**Data restrictions and Licence**	**Barrier**	**Stakeholder**
Name of data, URL if available Data owner	*Describe the data that the source provides*	*Describe why it is necessary and the benefit of accessing that data*	– *Data format* – *size* – *APIs metadata description* – *Ontologies* – *Use of Persistent Identifiers* – *Use of Standards*	*Give information on any restrictions on data, and data licences assigned or Data Sharing agreements – share if available.*	*Describe the barrier and assign a barrier from the list*	*Assign which stakeholder(s) this barrier affects*
FlightRadar24	Daily Arrivals/Departures at UK airports	Simulation schedule	Data converted to XLSX data	None	N/A	N/A

1.6 Results Data

As mentioned previously, data will be open-source databases and used for model validation. In addition, data will be created in the form of algorithms/software, using the DAFNI platform. A research plan was submitted for approval within the Cranfield University ethical approval system (CURES) in accordance with the research ethics and research integrity policy statements. Ownership of created data rests jointly with researchers and their institution, stored on the DAFNI platform with local computer backups managed by Cranfield University IT. Access and security of local computers are overseen by the Cranfield University IT department to guarantee data integrity throughout the process. At the end of the project, data will be shared as open source with the MIT license through the DAFNI platform. Secure retention and sharing will be enabled through the Cranfield University data repository (CORD), ensuring a minimum of 10-year preservation.

The project was intentionally designed with the flexibility in mind, ensuring that the algorithm can be applied to a wide range of datasets as long as the data adheres to the required format. To facilitate this, all the data has been consolidated into a single Excel spreadsheet, with each of the 34 airports organized into separate tabs. This structure not only simplifies navigation but also allows easy updates and modifications. Users can adjust the data to explore different scenarios, such as changes in stand availability, making the tool highly versatile for both current and future use cases. At the end of the project, the latest version of the algorithm will be uploaded alongside a mock dataset. This dataset will serve as an example to guide users in formatting their own data to ensure compatibility with the tool. A comprehensive description will be included, detailing the structure and requirements of the data, such as the parameters needed for accurate simulations. This approach ensures that the algorithm remains a practical and accessible resource, enabling users to adapt it to their specific needs and further extends its applicability to a variety of operational planning and resilience-building activities.

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1.7 Lessons Learnt and Recommendations

The project has been progressing well, with the first prototype of the tool successfully developed and on track with our defined timeline. Strong existing relationships and trust with ODLG members have been crucial in verifying the accuracy of the data, ensuring that the simulation outputs are reliable. During the project, we also discovered that EUROCONTROL is working on an operational mass diversion tool. However, its introduction into service is uncertain and likely years away. Our simulation tool is complementary to their efforts, offering value for tabletop exercises and scenario planning. A visit to EUROCONTROL HQ allowed us to exchange ideas. Demonstrations of the first prototype to the CAA, DfT and NATS have been very positive and as mentioned earlier, we also demonstrated the tool to other aviation stakeholders on 24th February 2025. We have collected the feedback and planning to present the final version to EUROCONTROL at the end of the project.

The initial development of the tool was made possible through the DAFNI grant, enabling the creation of the tool's first version. However, there is vast potential for further development. Currently, the simulation includes 34 UK commercial airport, but the underlying algorithm is inherently scalable. This makes it feasible to expand the tool to cover the European aviation system, offering insights into a broader network of diversion scenarios in a European context. Beyond geographical expansion, there are significant opportunities to enhance the tool's functionality. Adding more detailed operational parameters, such as specific terminal operations at diversion airports, could increase its precision. Furthermore, we see potential in extending the tool to model passenger flow and intermodal transportation following diversions. This idea would allow the simulation to analyse the additional demand placed on airport infrastructure and explore how hinterland connectivity, such as trans or buses, could accommodate a sudden influx of passengers. By doing so, the tool could support more holistic crisis planning, evaluating not only the immediate impacts of diversions but also their cascading effect on transportation networks and passenger.

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Appendices

Appendix A: Project Brief shared with industry stakeholders

MARS

Modelling Aviation Resilience Scenarios

for the UK Aviation System

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Background

Mass diversion events present a major challenge to the UK aviation system. These events place significantly operational pressure on the network and substantially increase the workload for the air traffic control officers, who must quickly identify multiple suitable diversion airports. This process can be quite time-consuming, which could lead to multiple fuel emergencies, thereby compromising the stability of the aviation system. An important contributing factor is limited spare capacity in the system, a consequence of high utilization at the major UK airports as highlighted by a 2017 study conducted by the Civil Aviation Authority.

Objectives

The Mass Diversion Simulation Tool (MassDivST) simulates airport closures within the UK aviation system and models the subsequent diversion process. Using pre-defined input criteria, an algorithm calculates optimal diversion airports for affected flights without compromising the operation at these alternative aerodromes. The outputs can be used to identify potential bottlenecks and support discussions on creating additional buffer capacity in the UK aviation system, such as increasing pre-approved diversion slots at airports.

Algorithm Design

A digital model of the 34 largest UK commercial airports have been designed and MassDivST uses historical data on arrival and departures at those airports. The user can simulate the closure of a selected airport for different time periods to observe the diversion dynamics.

Key Parameters for Diversion Decision

The algorithm identifies the most suitable diversion airport for each aircraft scheduled to arrive during the closure period. It evaluates alternate airports based on the following parameters:

- Declared diversion priorities
- Available stands at diversion airports
- Distance to nearest airport
- Contractual agreements

Declared Diversion Priorities

The tool considers up to two declared diversion airports per flight. However, due to multiple aircraft designating the same diversion airports in their flight plans and the capacity constraints at those locations, alternative airports are often necessary.

Available stands at diversion airports

All aircraft types have been converted to aircraft categories based on their wingspan (see Table 1).

Table 1 Aircraft categories

Code letter	Wingspan
B	15 – 24 m
C	24 – 36 m
D	36 – 52 m
E	52 – 65 m
F	65 – 80 m

The initial number of available stands at each airport can be adjusted within the simulation, enabling the modelling of various scenarios. For instance, Airport A might have the following stand availability at the start of the simulation as shown in Table 2.

Table 2 Example for available aircraft stands at airport

Airport A				
B	C	D	E	F
0	8	3	1	1

The stand availability is dynamically updated during simulations as flights arrive and depart. It is important to note that smaller aircraft can use larger stands, but the reverse is not possible.

Distance to nearest airport

Using GPS data, MassDivST calculates the distance to the nearest diversion airport, estimates the additional flight time, and checks if a stand is available at the calculated arrival time.

Contractual agreements

Agreements, for example, between airlines and ground handlers further restrict diversion options. A compatibility matrix within the dataset ensures compliance with these agreements (see Table 3).

Table 3 Example for contractual agreements at airports

	Airport A	Airport B	Airport C	Airport D	…
Airline 1	Yes	Yes	No	No	
Airline 2	No	Yes	Yes	Yes	
Airline 3	No	No	Yes	No	
…					

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Simulation Outputs

The MassDivST generates several post simulation reports.

Overview of Diversion Airports

The tool will provide an overview of the total number of diversions during the selected closure period, along with a breakdown of the airports to which the aircraft were diverted. Figure 1 shows the results of a three-hour closure at London Gatwick from 12:00 – 15:00 UTC.
Additionally, a map of UK airports is generated, providing a visual reference of the diversions. Users can click on individual airports to view the number of aircraft diverted to each location (Figure 2).

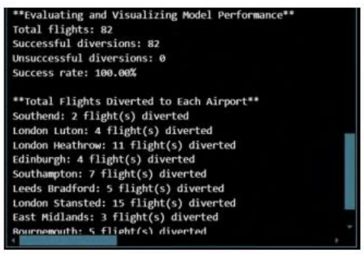

Figure 1 Breakdown of diverted flights by alternate airport

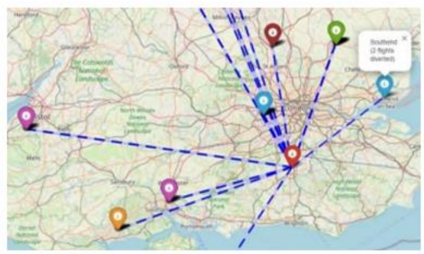

Figure 2 Interactive map displaying diversion airports

A detailed list of all diverted flights is also provided, showing their corresponding diversion airports and updated arrival times based on the distance to the alternative airport (Figure 3).

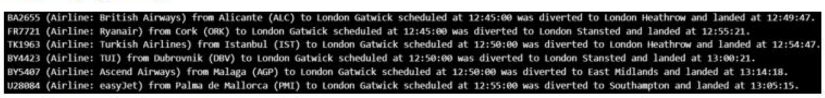

Figure 3 Flight-by-flight list showing diversion destinations and updated arrival times

Get in touch

For inquiries or collaboration opportunities, please contact: f.steinmann@cranfield.ac.uk.

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