IMPACT MONITOR

D4.3 – Delivery of Final Dashboard Application

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Abstract

This deliverable provides an overview of the Impact Monitor Dashboard Application, outlining its key objectives, components, and validation approach. The Impact Monitor Project aims to establish a coherent, multilevel framework for assessing the environmental, economic, and societal impact of European aviation research and innovation (R&I). The Impact Monitor framework consists of two interrelated components:

- A scalable, open source, distributed, and multidisciplinary collaborative environment, developed to facilitate collaborative assessment studies for air transport systems.
- A web-based environment (Dashboard Application), which operates in the post-processing stage to support design space exploration and analysis of study outcomes.

The Impact Monitor Framework (i.e. design environment and dashboard application) undergoes validation through three distinct Use Cases (UCs). These use cases serve to demonstrate the framework's capabilities and assess the functionality of the Dashboard Application.

This deliverable specifically outlines the summary of the conceptualization, design and development process of the Dashboard Application and provides insights on the demonstration use cases.

Keywords

Web Based Visual Analytics, Design Space Exploration, Dashboard Application, Impact Assessment

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1. INTRODUCTION

Aviation is a key driver of the European economy, supporting employment, tourism, and global trade. However, it also presents environmental challenges such as greenhouse gas emissions, noise pollution, and air quality concerns. The European Union's Horizon 2020-funded Impact Monitor project seeks to enhance aviation sustainability through research and innovation (R&I) assessment.

One of the primary goals of the Impact Monitor project was to develop the Multilayered Dashboard Application (DA), which serves as a visual and analytical platform for impact assessment. The DA is designed to provide decision-makers with high-level insights while allowing researchers to conduct in-depth studies on specific aviation components. By integrating interactive data visualization, real-time analytics, and external dataset compatibility, the DA supports more informed decision-making and enhances the efficiency of aviation R&I investments. Dashboard Application (DA) is an interactive web-based tool designed for data analysis and visualization at multiple levels, including aircraft, airport, and air traffic system. Unlike existing aviation dashboards that offer limited, user-specific insights, this DA provides a comprehensive, multi-perspective view as shown in Figure 1, enabling both decision-makers and researchers to conduct detailed analyses and trade-off studies. Users can interact with external datasets, explore aviation components at varying depths, and facilitate more effective decision-making.

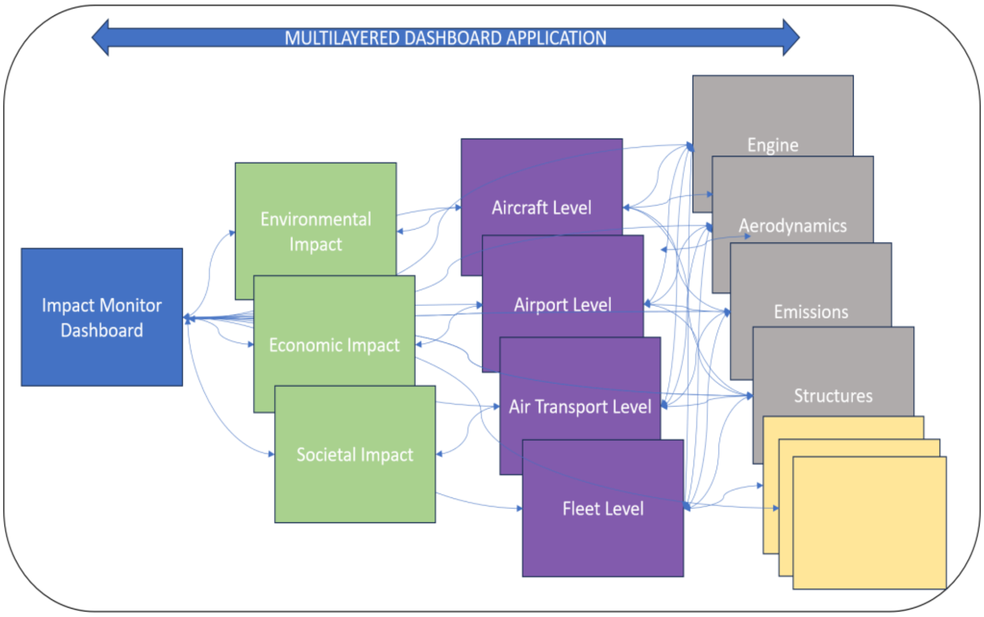

Figure 1: Multilayered Dashboard Application

This report presents an overview of the project's objectives, the methodology used in the development of the DA, its software architecture, and its application through various case studies. Additionally, it highlights the progress made so far and outlines future directions for improving and expanding the capabilities of the DA.

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2. Development of the Multilayered Dashboard Application (DA)

2.1 Methodology

This section presents the methodology that was used to develop the DA for the Impact Monitor Project. The development of the DA followed a structured three-phase methodology, as illustrated in Figure 2.

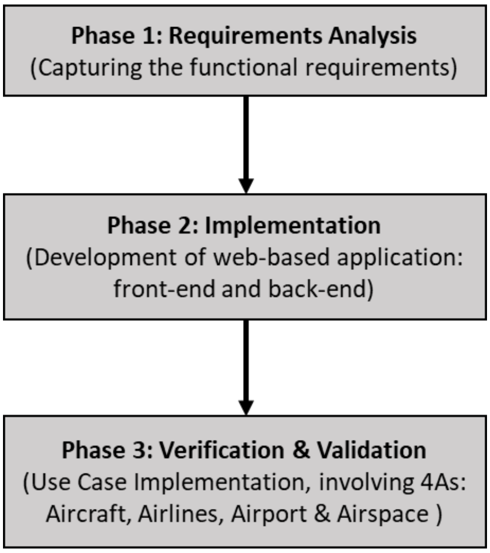

Figure 2: Methodology

The first phase focused on gathering and specifying requirements for the architecture of the DA. This involved multiple discussions with stakeholders and disciplinary experts to identify critical functionalities and visualization tools needed for impact assessment. Key requirements included the ability to display complex aviation datasets through interactive visual elements such as scatter plots, contour plots, and parallel coordinate plots.

In the second phase, the implementation of the DA took place, incorporating state-of-the-art technologies for web-based applications. The platform was designed to feature both a front-end and a back-end system, ensuring seamless interaction and analysis. The front-end was developed to be accessible through modern web browsers, offering users various visualization tools and aircraft data representations, such as drag polars, engine decks, and payload-range diagrams. The back-end architecture was structured around a service-based framework, using a REST API to enable data storage, retrieval, and statistical analysis.

The final phase involved verification and validation, where the DA was tested through multiple use cases to assess its effectiveness and usability. These case studies were designed to evaluate the DA's ability to analyze impact at different levels, such as aircraft, airport, and air transport systems (ATS). The insights gained from these assessments helped refine the DA to ensure it meets the needs of various stakeholders in the aviation sector.

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2.2 Requirement Specification

The DA was developed based on a set of well-defined requirements categorized into three main areas: Graphical User Interface (GUI), Data and Security, and Functional Capabilities. The GUI requirements emphasized the need for an intuitive, responsive, and visually appealing interface that could be accessed via web browsers and mobile devices. Special attention was given to ensuring a seamless user experience, with interactive graphs and visualization tools playing a central role in facilitating decision-making.

From a data and security perspective, the DA was designed to incorporate robust authentication mechanisms, ensuring secure user access and data protection. The system was also built to support various data formats including CSV (Comma Separated Values) and CPACS (Common Parametric Aircraft Configuration Schema) for visualization and analysis but mostly focusing on the CPACS format allowing users to work with one standard and true source of data. Furthermore, data storage and retrieval processes were optimized to provide real-time access to critical information by utilizing the Next Cloud.

The functional requirements of the DA included the ability to generate multiple types of interactive plots, enable interconnectivity between visualization elements, and allow users to manipulate and filter data efficiently. Additionally, the DA was equipped with functionalities for performing "what-if" scenario analyses, design exploration, and comparative studies. To enhance collaboration, users were also given the capability to generate, download, and share reports, facilitating evidence-based decision-making and policy formulation.

2.3 Architecture, Design and Development

This section presents the proposed web-based architecture of the DA for the Impact Monitor project, as illustrated in Figure 3. The software architecture can be divided into two parts, i.e., front-end and back-end.

The front-end consists of the JavaScript components which is accessible through modern web browsers and features graphical user interface (GUI) and visualization widgets, such as scatter plots, parallel coordinates plots, and surface plots, along with aircraft data and geometry representations, including drag polars, engine decks, flight envelopes, and payload-range diagrams.

The back-end of the application utilizes a service-based architecture powered by a REST API, facilitating data manipulation (storage and retrieval) and data analytics (statistical operations, filtering, and ranking).

It is important to mention that the unidirectional arrows in Figure 3 represent the read access to the stored data, i.e., the DA only reads the data, while writing the data is performed through a Nextcloud interface in the collaborative Impact Assessment Framework developed in the Impact Monitor research project.

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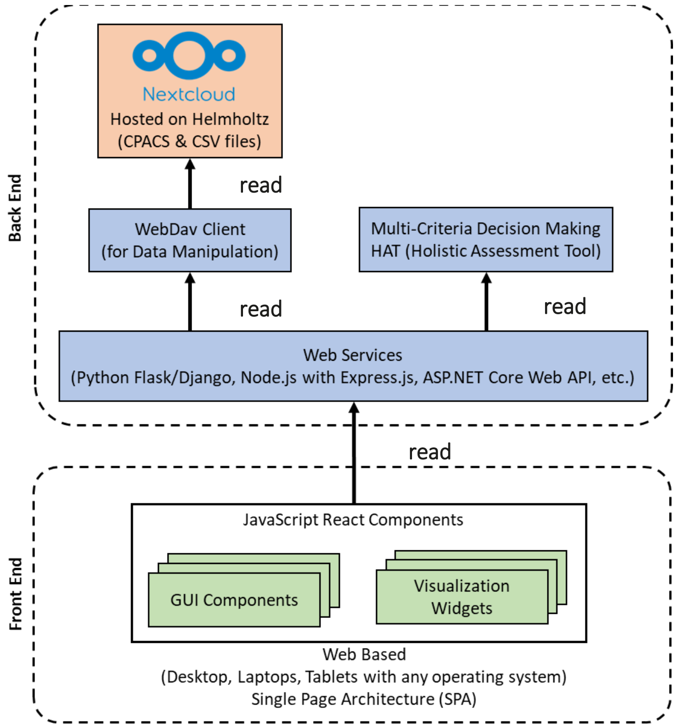

Figure 3: Architecture of the DA

Development of the DA was carried out on top of the designed wireframes/designs of the GUI and driven by the detailed requirements, which were outlined in the previous deliverable 4.2. In the remainder of this section, the individual components of the architecture are described in detail.

2.3.1 Graphical User Interface (GUI) Components: Front-End

The main requirement for the DA was that the application should be web-based, quick and accessible from any modern web browser. Therefore, it was decided to employ single page application (SPA) architecture for the development of web-based application. SPA is a web application architecture where the entire application runs within a single web page, dynamically updating content without requiring full page reloads, hence, resulting in a fast and responsive user experience. There are various JavaScript libraries for the development of SPA web-based applications, such as, Angular, React.js, and Vue.js, however, React.js was selected for the development of the user interface. React.js is an open-source JavaScript library developed and maintained by Facebook for building user interfaces, particularly single-page applications (SPAs) where efficient rendering of dynamic data is crucial. React also supports unidirectional data flow and component-based architecture, which simplifies the development and maintenance of complex web applications.

One of the limitations in the existing applications for impact analysis of ATS is that these applications provide fixed dashboards, i.e., the user is not able to create dashboards dynamically. Therefore, it was decided to employ a docking layout control for creating dynamic dashboards. Several notable JavaScript libraries for providing dynamic docking exist, such as rc-dock, Golden Layout, React Mosaic, FlexLayout, React Docky, React Grid Layout, etc., however, rc-dock was employed for the Impact Monitor DA, which is an open-source React component library that provides a flexible docking layout system for building complex user interfaces. It enables developers to create resizable, draggable, and dockable panels within React applications, facilitating the organization of content in a dynamic and user-friendly manner. The library supports features such as nested layouts, tabbed panels, and

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customizable themes, making it suitable for applications requiring sophisticated window management, such as data analysis tools. Figure 4shows a screenshot with the capability to dynamically arrange and resize the dashboard elements.

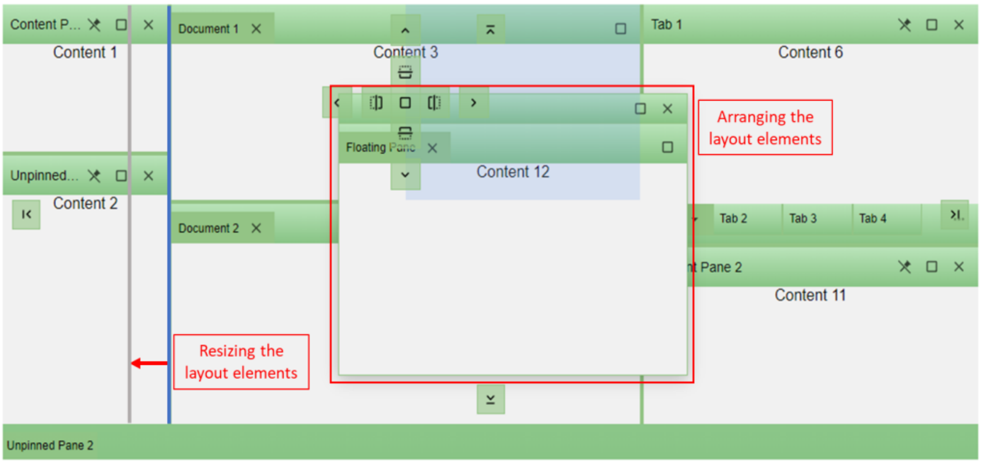

Figure 4: Dynamic Arrangement and Resizing

A number of web pages and features (React components) were developed utilizing the React library for the different functionalities of the DA, as outlined in the requirements of the DA as illustrated in the Figure 5. These web pages and functionalities provides the capabilities for the user to generate and view multiple plots, styles and dashboards.

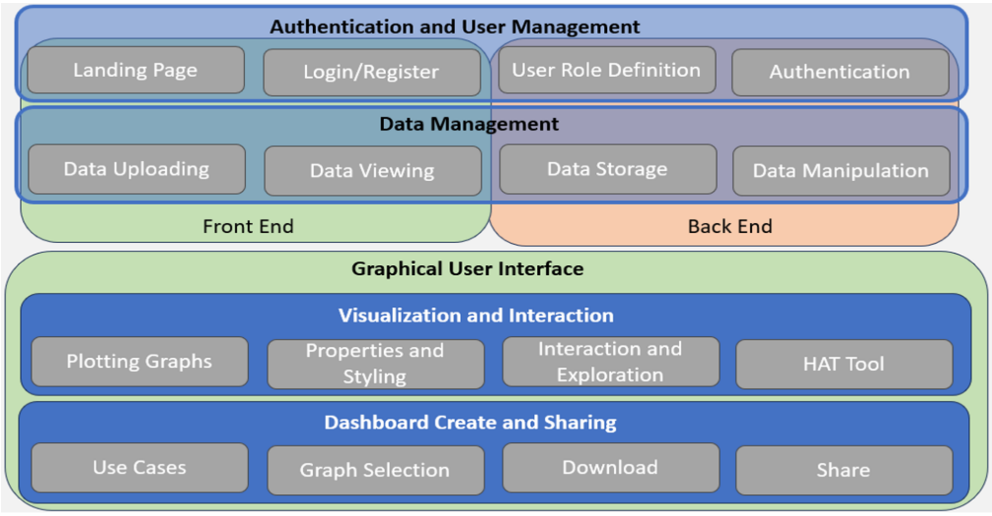

Figure 5: React Components for DA

2.3.2 Visualization Widgets: Front-End

In addition to the user interface, the other type of front-end components for the DA are visualization widgets. The main goal is to develop an interactive visualization environment for rapid exploration of the potential design solutions. To achieve this, several interactive visualization plots (e.g., scatter plots, parallel coordinates plot, surface plots, bar charts, pie chart, etc.) are required, which are then synchronized together so that a change in a design point in one plot is reflected simultaneously across all the other plots. There are several JavaScript libraries available for data visualization, such as Plotly, Highcharts, AnyChart, however, these libraries provide higher-level abstractions with pre-built chart types. Another JavaScript library for data visualization is D3, which is a low-level library offering fine-

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grained control over every visual element. Furthermore, D3 is excellent for performance optimization since it works directly with SVG and Canvas, which is beneficial for large datasets. Therefore, D3 was selected for the Impact Monitor DA due to its ability to create highly customized optimized visualizations.

Most of the existing tools allow the users to create static visualization plots, however, the DA provides the capability to create interactive synchronized plots, e.g., giving the freedom to modify on the fly both the design points and the constraints, as illustrated in Figure 6. Furthermore, by clicking the points in the design space enable the designer to identify how the performance is changed.

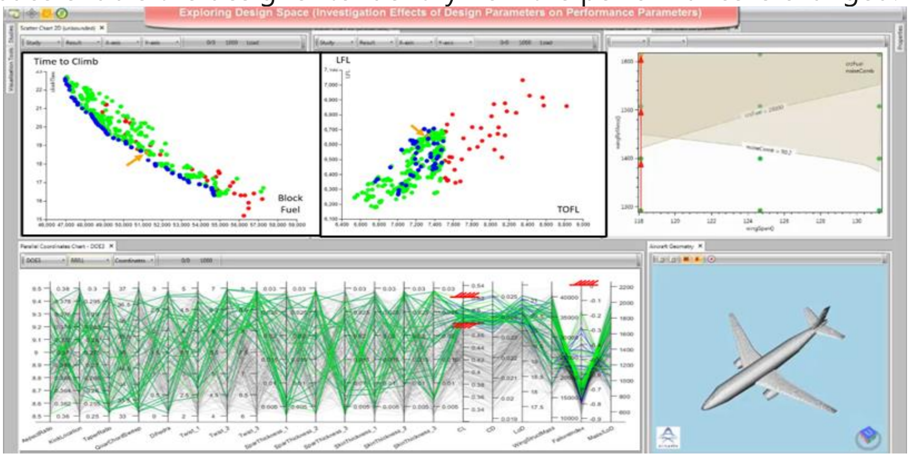

Figure 6: Interactive Synchronized Visualization Widgets

The rest of this section presents different types of the visualization plots developed using D3 for the DA. Scatter plots are one of the simplest types of visualizations. It is limited to two dimensions, i.e., displays the relationship between two numeric parameters. The parallel coordinates plot allows visualization of high-dimensional spaces, where each design solution is represented as a polyline with vertices on the (parallel) vertical axes. Parallel coordinates plot allows to compare the feature of several individual observations (series) on a set of numeric variables. Each vertical bar represents a parameter and has its own scale. Values are then plotted as series of lines connected across each axis. Another useful plot is the constraints iso-contours plot, which divides the multi-dimensional design space into multiple 2D projections or slices (contour plots) which show the contour line (also called isoline) of the constraints for two design variables along which the constraint has a constant value. This allows the decision maker to gain insight into the topology of the feasible region(s) within the design space. For example, the designer is able to visualize the active constraints of a study and identify the ones that prevent him/her from obtaining the largest feasible space possible, and consequently, from gaining the full benefits of the design concept. Another visualization widget implemented for the DA is self-organizing map. It is a type of artificial neural network (ANN) and is used for dimensionality reduction. It is trained using unsupervised learning to produce a low-dimensional (typically two-dimensional), discretized representation of the highly dimensional input space, called a map. For the visualization of route networks (flights), noise contours, 2D map visualization are implemented. These visualization widgets are useful for displaying information about multiple designs in a single plot. Apart from these, visualization widgets templates for displaying data regarding single aircraft, e.g., drag polars, engine performance decks, flight envelops, and payload-range diagrams are also implemented for the DA.

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2.3.3 Trade-off and What-if Studies through Visualization Widgets

This section describes the capabilities implemented for interactive filtering, ranking through multi-criteria decision making and Pareto classification of the data from the visualization plots.
Figure 7 shows an illustration where the user selects some design points interactively by clicking and dragging the mouse (represented by rectangle). Since all the plots are interlinked and synchronized, therefore, the selected design solutions are also highlighted in all the other plots.

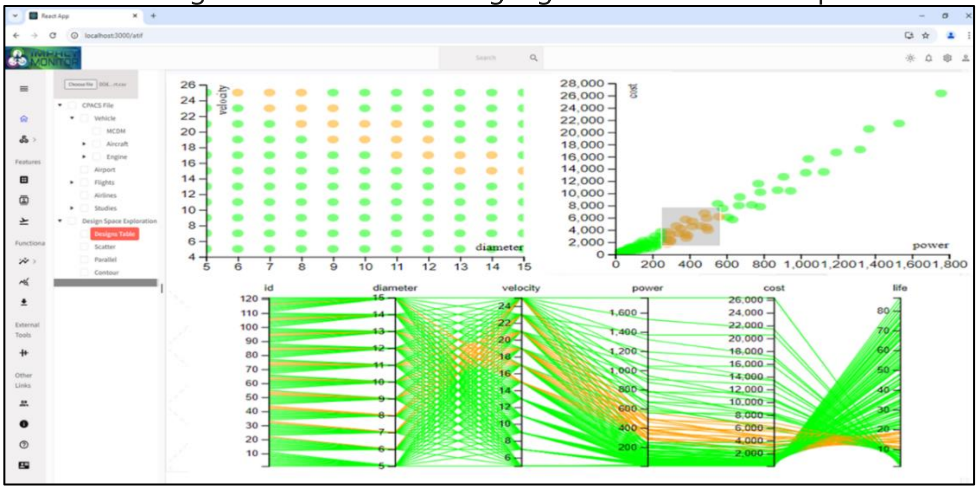

Figure 7: Data Filtering

In addition to filtering through interactive selection, multi-criteria decision making (MCDM) and Pareto filtering capabilities are implemented for classifying and down-selecting design solutions. This is particularly useful when displaying the results of design of experiments and optimization studies.

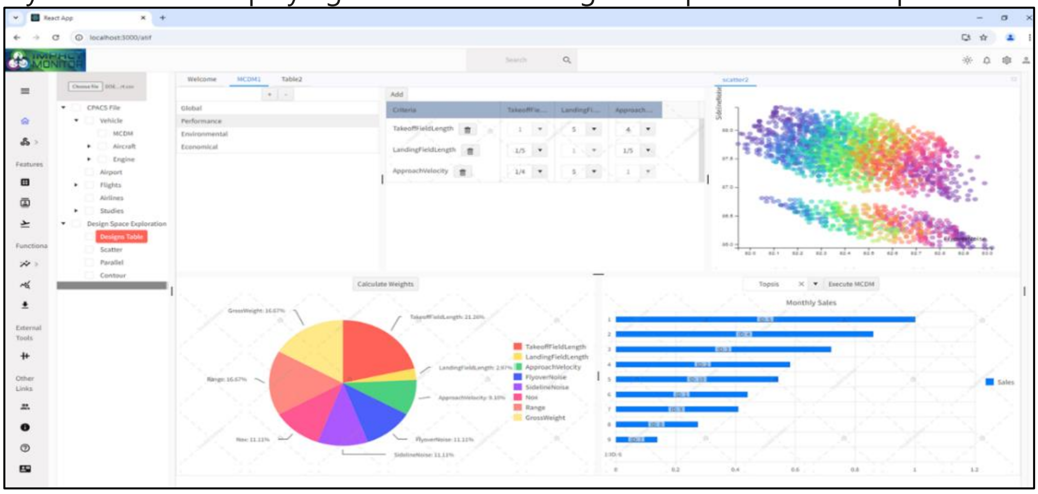

Figure 8: Ranking through Multi-Criteria Decision Making

Figure 8 shows an illustration of classifying design solutions according to MCDM. Here, three categories of criteria, i.e., Performance, Environmental, and Economical are considered for sustainability analysis. The Performance category consists of Range, Takeoff Field Length, and Approach Velocity, whereas, Environmental category is comprised of Noise and Nox Emissions, and finally, Operating Cost is considered for Economic category. After specifying the weights for the pairwise comparisons, the global weights are determined and then, depending on the selected MCDM method, ranking of the design solutions is displayed through color axis.

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2.3.4 Data Manipulation: Back-End

This section describes the implemented data manipulation strategies in the DA. The implemented strategies allow the users to load data from a variety of sources, including Impact Monitor's internal data repository, and other public data sources. The data is ingested and transformed into a common format using data pipelines and data integration tools. This data is then stored in a centralised data repository, which is accessible to all components of the application. For the current study, NextCloud is employed for data storage. NextCloud is an open-source suite of client-server software designed for creating and utilizing file hosting services. It provides functionalities similar to proprietary platforms like Dropbox, Office 365, or Google Drive, enabling users to store, sync, and share files, calendars, contacts, and more across different devices. NextCloud can be deployed on-premises or hosted in the cloud, providing flexibility and control over data management.

The data is generated by Impact Assessment Framework via RCE in the CPACS data format. CPACS provides a standardized hierarchical parametrization of air transportation systems implemented via XML Schema Definition (XSD). A common semantic description of detailed aircraft design and analysis data (e.g., geometry, structures, aerodynamics, flight performance, etc.) facilitates the robust integration of various tools used in multidisciplinary design analysis and optimization. In addition, CPACS supports studies on impact assessment of air transportation systems through standardized descriptions of airports and flight schedules.

For displaying the results from design studies, such as design of experiments, optimization, and sensitivity analysis, individual CPACS files are combined into CSV (Comma Separated Values) or JSON (Java Script Object Notation) files for visualization. CSV is a very common file type for storing results of multiple aircraft solutions, which can be accessed from the remote computer or remote central server. However, data stored as JSON is particularly very useful for transferring data as strings (a data type used to represent a sequence of one or more alphanumeric characters) over the network from one computer to another.

To access the data generated by the Impact Monitor framework, REST API web services were created via Python Flask. Flask is a lightweight and flexible web framework for Python, designed to simplify the development of web applications and APIs. It adopts a micro-framework architecture, meaning that it provides core functionalities like routing, request handling, and templating, while additional features such as database integration and authentication can be added through extensions.

WebDAV (Web Distributed Authoring and Versioning) was used to access CPACS and CSV files (stored in the Nextcloud) from the DA. WebDAV is a standard protocol that extends the Hypertext Transfer Protocol (HTTP/1.1) to enable collaborative editing and file management on remote web servers. It allows users to create, edit, move, and delete files directly on a web server as if they were working with local storage, making it ideal for cloud storage solutions such as Nextcloud.

2.3.5 Security Implementation of Data and Web Services

Since the data for the DA is stored in the cloud, an authentication-authorization mechanism is implemented to verify the user's identity and access to various resources. This approach utilizes Azure Active directory B2C. It is a customer identity access management (CIAM) solution that uses standard authentication and authorization protocols, i.e., OAuth 2.0, OpenID Connect (OIDC), and Security Assertion Markup Language (SAML). The process of securing the microservices consists of two steps. First, the user signs-in using Microsoft Authentication Library (MSAL) for .NET and obtains a JSON Web Token (JWT) access token from Azure Active Directory B2C. JWT is an open standard (RFC 7519) for the secure communication of digitally signed information. Once the JWT is available, the microservices can be consumed by using the JWT as a bearer token in the header of the HTTP request.

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2.3.6 Multi-Layer Dashboard Implementation

A strategy for creating multiple layers of dashboard is implemented in the DA. As shown in Figure 9, we can see the implementation of a top-to-bottom layer methodology has been performed where users can start at a high-level view on studies and can go further into subsequent level and vice versa. For example, a decision maker may want to view an impact study at airport level to understand the environmental and economic aspects, but if he/she also wants to go into the details of a particular aircraft, it is easily feasible and can be examined in further detail at the engine or fuel type level. Also, the Dashboard Application is capable of performing what-if scenarios like what will be the impact at top level if fuel has been changed from kerosene to SAF or hydrogen. Such capabilities and studies can easily be performed using this multilayered architecture of the DA.

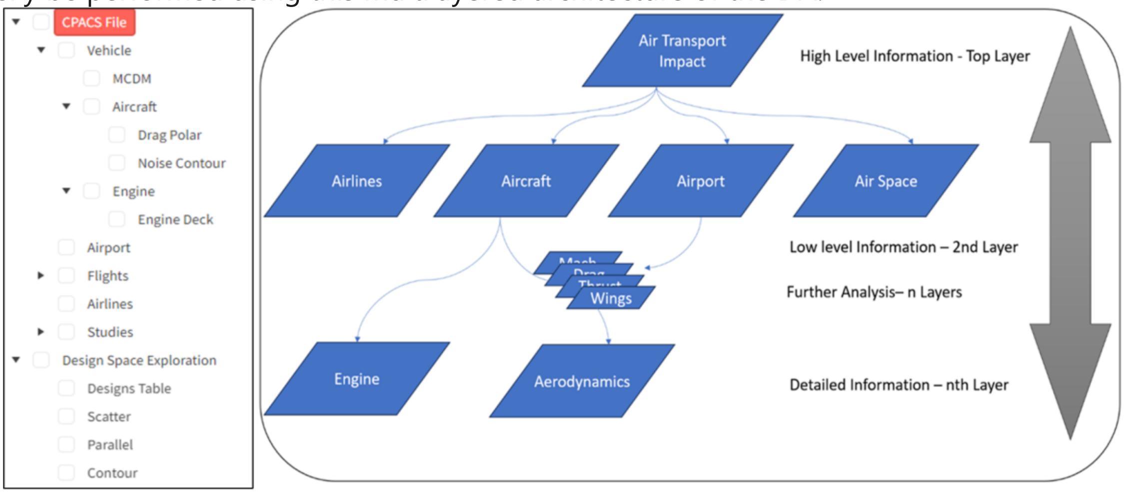

Figure 9: Architecture of the Multilayered Dashboard

2.4 Use Case Demonstration

To evaluate the effectiveness of the DA, three case studies were conducted at different levels of the aviation system as depicted in Figure 10. The first case study focused on the aircraft level, assessing the impact of advanced propulsion technologies on fuel efficiency and emissions. The second case study examined the airport level, analysing the benefits of continuous descent operations in reducing fuel consumption and noise pollution. The third case study addressed the ATS level, evaluating policy measures for the adoption of sustainable aviation fuels (SAF).

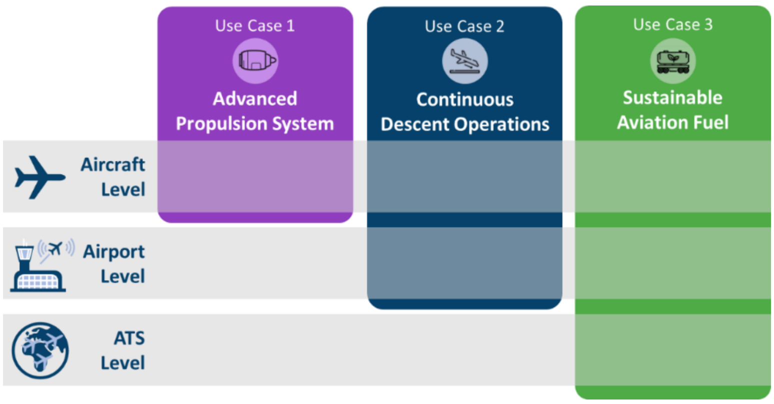

Figure 10: Schematic Representation of the Demonstration Use Cases and Assessment Levels

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Main idea behind these use case studies, and demonstration was to validate and demonstrate the features and capabilities of the Impact Monitor Framework and DA. A more detailed discussion and process with results for all the three use cases has been discussed in the below subsections.

2.4.1 Aircraft-Level Dashboard – Use Case 1

In this section, the first use case at aircraft level for the advanced propulsion systems has been implemented using the Impact Monitor framework and the results are presented through Dashboard. The use case involves the collaborative design and analysis of a single-aisle, tube-and-wing, low-wing configuration, with two wing-mounted turbofan engines, and conventional empennage.

For airframe sizing, design variables (wing area and aspect ratio) and top-level aircraft requirements are utilized to calculate the engine thrust requirements, which are then transferred in a CPACS file to the engine sizing model using Uplink protocol.

The two tools employed for sizing airframe and engine cycle analysis are SUAVE and TURBOMATCH, respectively. The first step in the aircraft engine sizing loop is to define the basic aircraft and mission in SUAVE. Once the convergence between airframe and engine design teams is achieved, the optimized aircraft can be utilized for emissions assessment, where 4D trajectory analysis is performed. This part of workflow involves other two tools named DYNAMO and AECCI. After mentioned complete workflow is completed and datasets are created, they are visualised and analysed in the DA using various plots and dashboards as shown in Figure 11 and Figure 12. Further details of the use case are presented in [3].

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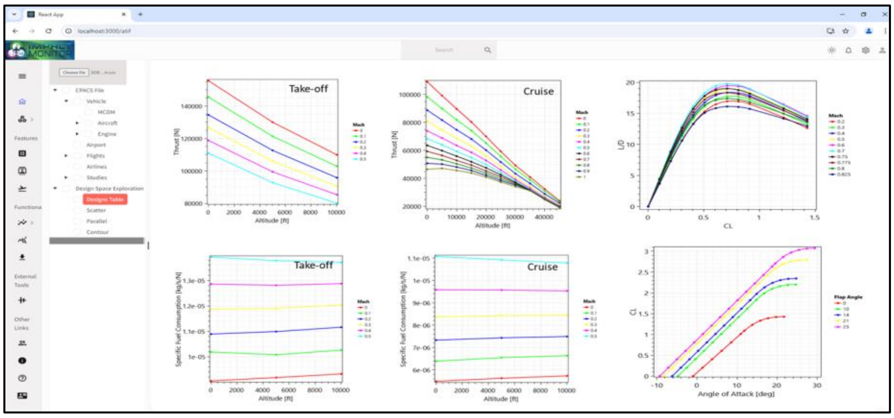

Figure 11: Use Case 1 Dashboard (Visualizing Engine Deck and Drag Polars)

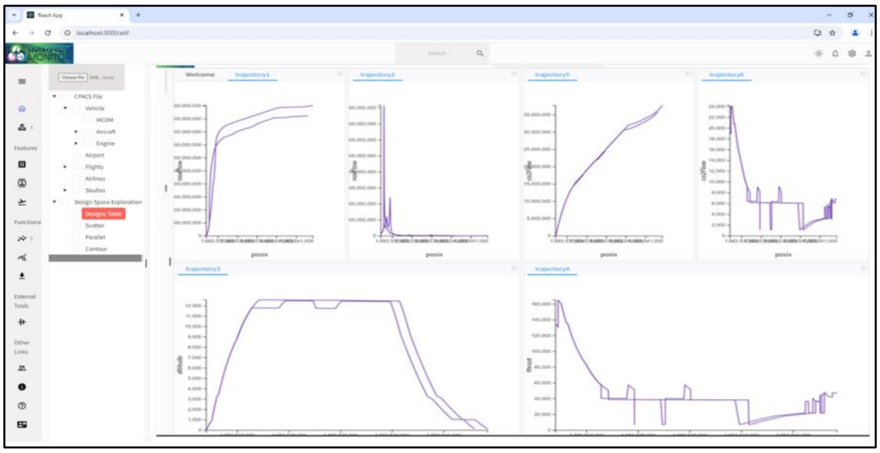

Figure 12: Use Case 1 Dashboard (Visualizing Emissions)

2.4.2 Airport-Level Dashboard – Use Case 2

This section presents the use case at the airport level for the impact-assessment of continuous descent operations (CDO). CDOs allow aircraft to follow an optimum flight path that delivers major environmental and economic benefits, giving as a result engine-idle continuous descents that reduce fuel consumption, pollutant emissions and noise nuisance. A set of tools including Scheduler (DLR, flight schedule simulation), AirTOp (available at NLR, TMA simulation), Dynamo/Farm (UPC, Trajectory simulation and assessment), LEAS-iT (NLR, Emissions simulation), Tuna (NLR, noise simulation, AECCI (ONERA, emissions simulation), TRIPAC (NLR, risk simulation) and SCBA (TML, social and economic impact assessment) were employed. This use case on CDOs explores the impacts of this ATM strategy on the sustainability of these operations.

Similar to use case 1 results, Figure 13 shows the generated dashboard depicting various visualizations from different tools involved in use case 2 including a graphical representation of a set of trajectories obtained by AirTOp and the postprocessed data from DYNAMO/FARM trajectories. And the dashboard in Figure 14 provides visualization on the emissions (CO_2 and NOx emissions, NOx and accumulated NOx) by AECCI and contour maps suggesting the noise footprints and risk footprints from Tuna and TRIPAC tools respectively. Further details of the use case are available in [3].

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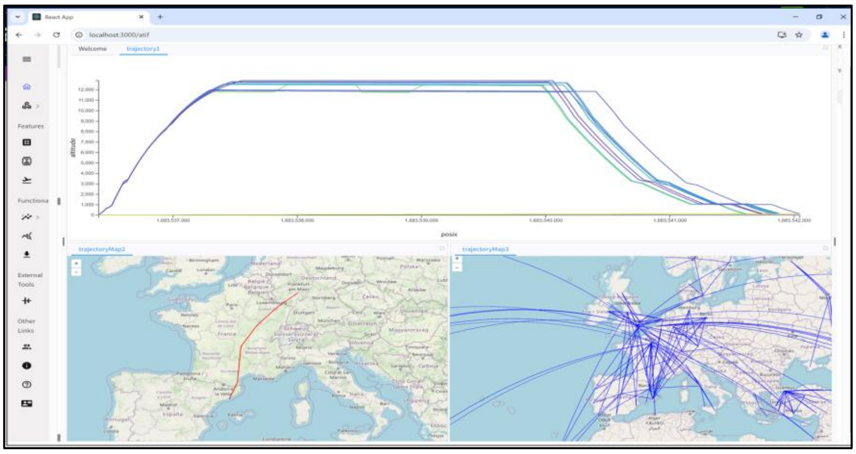

Figure 15: Use Case 2 Dashboard (Visualizing 4D Flight Trajectories)

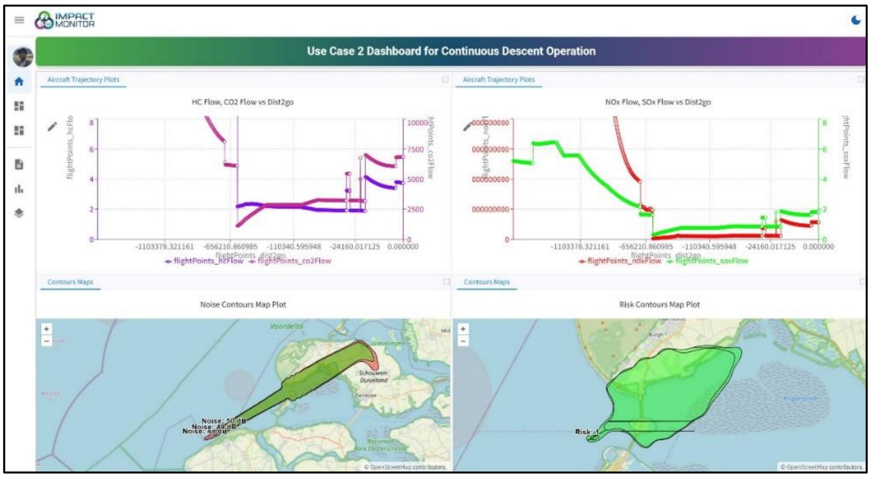

Figure 16: Use Case 2 Dashboard (Visualizing Emission during Flights)

2.4.3 Air Transport System-Level Dashboard - Use Case 3

In this section, the third use case at air transport system (ATS) level is presented for the impact assessment of different policies and strategies for the uptake of sustainable aviation fuels (SAF). Four tools including Schedular, Emissions Tool (TCM), TRAFUMA and ECOIO were employed for assessing the impacts of policy scenarios on a range of KPIs for the following impact categories: climate, emissions and air quality, economy, social impacts/quality of life, efficiency and effectiveness. Figure 17 and Figure 18 presents visualizations and dashboards created by the dataset generated in Use Case 3. Further details of the use case are presented in [4].

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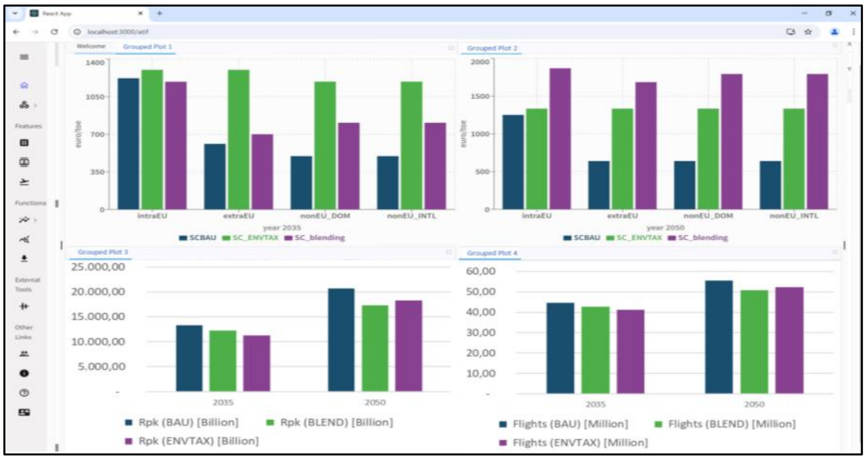

Figure 17: Use Case 3 Dashboard (Visualizing Fuel Cost and Revenue)

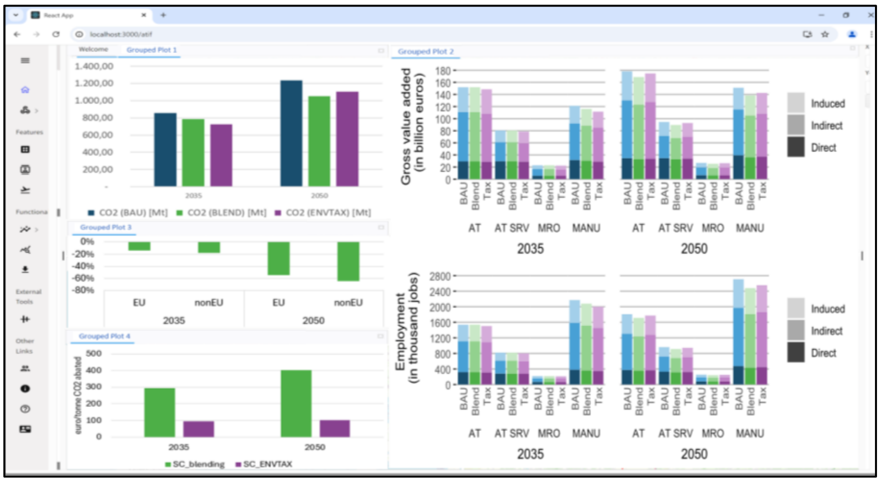

Figure 18: Use Case 3 Dashboard (Visualizing CO2 Emissions and Economic Impact)

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3. Lessons learnt

Throughout the development of the DA, several key lessons have emerged that can guide future R&I projects in the aviation sector. One significant takeaway is the importance of stakeholder collaboration in defining clear and practical requirements. Engaging decision-makers, researchers, and industry professionals early in the process ensured that the DA addressed the specific needs of diverse users.

Another lesson learned is the value of adopting an agile development approach, particularly validation through use cases. The iterative nature of the project allowed for continuous feedback and refinement, ultimately leading to a more robust and user-friendly tool. The use of state-of-the-art web technologies also highlighted the advantages of flexible and scalable system architectures, which facilitate seamless integration with external datasets and tools.

Additionally, the necessity of balancing high-level strategic insights with detailed technical analysis was a key consideration. Many existing decision-making tools focus solely on either policymakers or researchers, whereas the DA successfully bridges this gap by offering a multilayered approach. This ensures that both strategic and technical stakeholders can leverage the platform for their specific needs.

Finally, the project underscored the ongoing need for enhanced data security and authentication mechanisms in web-based decision-support tools. Ensuring secure access to sensitive data while maintaining ease of use was a challenge that required thoughtful implementation.

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4. Conclusions and Next Steps

The development of the DA as a part of Impact Monitor project represents a significant advancement in the field of aviation R&I impact assessment. By integrating interactive visualization, data analytics, and decision-support functionalities, the DA provides a robust platform for evaluating aviation sustainability initiatives.

Significant progress has been made in the development of the DA, with key milestones achieved and first stable version of DA has been completely developed and demonstrated. The core architecture has been implemented, incorporating all major functionalities outlined in the initial requirements (Deliverable 4.1). The DA has been deployed as a fully operational prototype, featuring an interactive visualization environment for aviation impact assessment. Additionally, preliminary testing has been conducted through selected use cases, demonstrating the DA's capabilities in real-world scenarios. With the implementation of the three use cases, it was demonstrated that the multilayered DA supports the user in informed decision making. This enables an enhanced efficiency and productivity with the associated cost reduction, and the facilitation of innovation and knowledge sharing. The main benefit of the dashboard is to holistically support the decision making by considering all the four A's of the air transport systems, i.e., aircraft, airline, airport, and airspace.

Despite these achievements, several areas require further development. One major focus is on expanding the DA's customization options, allowing users to tailor the platform according to their specific needs. Additionally, improvements in real-time data interaction will enhance the DA's functionality, enabling live decision-making capabilities. Future work will also involve broadening the range of case studies and integrating more advanced tools for sustainability assessments, such as life cycle analysis and environmental impact modelling.

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