



D3.8

Web-Based Frontend

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Pioneering resilient and adaptive multimodal transport networks

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1. Introduction

ReMuNet – Resilient Multimodal Freight Transport Network – is financed by the European Commission through the European Union’s Horizon Europe research and innovation programme under Grant Agreement No 101104072. It has been proposed by a consortium of 15 beneficiaries coordinated by FIR e. V. an der RWTH Aachen and is being carried out over 36 months, having started in July 2023. The content of the project and the aim of this deliverable will be presented in the following.

1.1 Project Background

ReMuNet is tasked with identifying and signalling disruptive events while assessing their impact on transport corridors. By communicating alternative multimodal transport routes to logistics operators and subsequently to truck drivers, train drivers, and barge captains, it facilitates a more rapid network response. Furthermore, ReMuNet orchestrates route and capacity utilisation and enables synchromodal relay transport.

Additionally, ReMuNet is responsible for establishing comprehensive standards for the transnational description of multimodal nodes and transport routes, including infrastructure elements and their parameters. This forms the basis for a unified modelling language. To ensure maximum practical applicability and acceptance, these standards are developed by evaluating and consolidating existing description standards, supplementing technical and sustainability-related descriptive attributes, and engaging in close collaboration with European transport companies, associations, and institutions.

ReMuNet’s collaborative platform reduces entry barriers for regional transport companies, encouraging participation in multimodal transport, known for its lower average emissions compared to road freight transport. Intelligent routing algorithms prioritise low-emission routes and modes of transport, enhancing transport efficiency and significantly cutting emissions. ReMuNet explores the integration of alternative drives to further support sustainability goals, aiding political and economic decision-makers in expanding and maintaining vital transport infrastructure.

To make this routing functionality accessible to stakeholders, ReMuNet provides a collaborative platform consisting of a backend integration layer and a web-based frontend. This deliverable addresses the frontend component of that platform, which visualises the routing results generated by the backend.

1.2 Key Objectives of the ReMuNet Project

The concept of the Physical Internet foresees a seamless network where resources and assets can be shared openly and efficiently. ReMuNet’s main objective is to support the achievement of this vision by giving the transport network the ability to prepare, respond, and adapt to disruptive events.

In practice, ReMuNet uses digital technologies to holistically improve the resilience of the logistics and freight transport network. This includes making planning more robust and secure, reducing response times, and speeding up system recovery. ReMuNet also takes environmental aspects into account and aims to provide synchromodal transport options

with the lowest emissions, thereby contributing to the implementation of the Physical Internet and reducing the environmental impact of freight transport.

ReMuNet's key objectives are to:

- Lay the foundation for a common standard to describe sustainable European multimodal transport networks for all stakeholders.
- Reduce European inland transport emissions on the main run by over 50 % in the long term.
- Enable the multimodal freight network to react and respond 20 % more quickly to disruptive events until 2026 (compared to 2021).
- Provide 50 % more alternative transport routes in the face of disruptive events and make multimodal route planning 10–20 % more accurate and efficient until 2026.
- Create new approaches for benefit-sharing, cost-efficient business models and integrate 30 % more companies (> 50 % SMEs) into the multimodal freight transport ecosystem.
- Predict the impact of disruptive events on multimodal transport corridors with 90 % higher accuracy until 2026.
- Enable civil protection organisations to set up aid-delivery logistics for crisis areas 25 % faster in 2026.
- Create a unified data pool that portrays the real-time utilisation of multimodal European transport infrastructure in compliance with data protection regulations.

The web-based frontend documented in this deliverable directly supports several of these objectives: it visualises low-emission route alternatives and makes the platform's routing and disruption information accessible and comparable for operational and project stakeholders, regardless of their own IT maturity.

1.3 Objective of Deliverable 3.8

This document describes the deliverable D3.8, the web-based frontend of ReMuNet, developed under Task T3.7. It is the second of two deliverables derived from the ReMuNet routing platform documentation; the first deliverable (T3.6) covers the collaborative platform backend and the interfaces for data and stakeholder integration on which this frontend builds.

The frontend is a browser-based application that visualizes, compares and inspects transport routing scenarios. It provides an interactive user interface for route planning and disruption analysis. The application retrieves routing data from the backend services (PTV and Mansio), prepares the data for presentation, filters routes according to defined restricted territories, and displays the resulting transport options on an interactive map. It supports the comparison of normal and disrupted scenarios and presents operational indicators such as travel time, distance, costs, CO2 emissions and route segment details.

In line with the objectives of T3.7, the frontend aims to give ReMuNet a user-friendly and uniform appearance that emphasizes neutrality through a simple design suited to the European context. The deliverable provides a usable web interface that makes backend-generated routing results accessible, understandable and comparable for end users.

1.4 From previous Deliverables to Deliverable 3.8

Deliverable 3.8 builds directly on the backend integration layer and interfaces documented in Deliverable 3.7. Where D3.7 established the data model and the REST API through which routing scenarios, route alternatives and handover information are exposed, D3.8 consumes these interfaces to provide a user-facing visualisation: it retrieves the routing data prepared by the backend, filters and transforms it for presentation, and displays the resulting transport options on an interactive map. As the second of two deliverables documenting the ReMuNet routing platform, this deliverable completes the platform's documentation by describing the layer through which end users actually interact with the routing results.

1.5 Structure of Deliverable 3.8

This deliverable is structured into the following chapters:

- Chapter 1 outlines the objective and scope of this deliverable
- Chapter 2 describes the purpose and objective of the frontend in more detail
- Chapter 3 describes the UI and UX design principles underlying the frontend
- Chapter 4 describes the implemented functionality of the frontend
- Chapter 5 describes the frontend architecture
- Chapter 6 describes the technology stack and its integration with the backend
- Chapter 7 describes the typical user workflow
- Chapter 8 describes deployment and hosting
- Chapter 9 summarises the result and status of the frontend implementation
- Chapter 10 defines the precise scope of the deliverable

2. Purpose and Objective

The objective of this deliverable is to provide a web-based visualization and decision-support tool for transport routing data, with a user interface and user experience that are uniform, neutral and simple to use.

The main goals are:

- Provide a clear visual representation of transport routes on a map.
- Allow users to select and compare different routing scenarios.
- Support the analysis of disrupted and non-disrupted transport situations.
- Present route details and key performance indicators in a compact form.
- Integrate backend routing and handover data into a single frontend view.

- Improve accessibility of routing results for operational and project stakeholders.
- Offer a uniform and neutral UI appearance through a simple, European-context-oriented design

3. UI and UX Design Principles

The user interface is designed to give ReMuNet a uniform and neutral appearance based on a simple, restrained visual style appropriate for use across the European context. Neutrality is supported by avoiding strong brand-specific styling and by relying on a consistent, component-based design language so that the appearance and interaction patterns remain uniform across the application.

A consistent component library and styling provide a coherent look and feel, and the interface supports both light and dark display modes, with the map tiles adapting to the selected theme. The responsive layout ensures that the application is usable on desktop devices as well as on smaller screens. Together, these choices keep the interface clear and approachable while keeping the focus on the routing information itself.

The user experience is structured around a straightforward flow: users select a scenario, choose between normal and disrupted conditions, and inspect and compare the resulting routes. Key information — metrics and route segments — is presented compactly so that transport options can be assessed quickly without a steep learning curve.

4. Implemented Functionality

The current implementation allows users to select available routing scenarios provided by the backend API and to switch between normal and disrupted routing scenarios. Routes are displayed on an interactive Leaflet-based map using geographic route data, and the map viewport automatically adjusts to fit the displayed routes.

Users can show or hide individual route alternatives, which are also presented in route comparison cards containing the relevant metrics and segment information. The interface displays transport metrics such as distance, travel duration, start and end times, costs and CO2 emissions, while individual route legs are shown with details including the mode of transport, origin, destination, distance and duration.

The platform can also include supplementary route and handover information from a second backend data source, and routes or tours can be filtered before display based on configured restricted territories. In addition, the user interface supports both light and dark display modes, with map tiles adapting to the selected theme, and the responsive layout ensures that the application is usable on desktop devices as well as smaller screen sizes.

5. Frontend Architecture

The frontend is implemented as a modern web application using Next.js and React. It communicates with a Java Spring Boot backend, which provides the REST API consumed by the web application. The Java backend integrates PTV and Mansio as external routing services that perform the route calculations, and the received data is mapped into internal domain models before being rendered in the user interface.

The application uses server-side data loading for the main route results and client-side interaction for scenario switching, route visibility controls, theme handling and map rendering. Route geometries are handled as GeoJSON-compatible data and rendered with Leaflet.

6. Technology Stack and Integration

The frontend is built with Next.js and uses TypeScript as the programming language. React is used as the frontend library, while Tailwind CSS provides the styling and the user interface is based on Radix UI components. Map rendering is implemented with Leaflet and React Leaflet, and Axios is used as the HTTP client. Zod is used for data validation and schemas, while GeoJSON helpers and Turf.js provide geospatial utilities, and date formatting is handled with date-fns.

The frontend is hosted internally and can be reached at:

- <https://remunet.bitsfabrik.com>

It consumes the backend REST API, which is hosted at:

- <https://digitaler-zwilling.bitsfabrik.com/api/>

The frontend uses the following environment variables for API configuration:

- MAIN_API_SERVICE_SERVER_URL for server-side API requests.
- NEXT_PUBLIC_MAIN_API_SERVICE_URL for client-side API requests.

7. User Workflow

The typical user workflow is:

- The user opens the web application.
- The application loads or redirects to a default routing scenario.
- The user selects a route scenario from the available backend-provided scenarios.
- The user selects either normal or disrupted mode.
- The application retrieves the corresponding route and handover data.
- The platform filters and transforms the data for display.
- The map shows the available route alternatives.
- The user inspects route cards and compares route metrics.
- The user toggles individual route alternatives on or off on the map.

8. Deployment and Hosting

The web-based routing platform is prepared for deployment through the existing Bitbucket Pipelines setup. The pipeline installs the required Node.js dependencies, builds the Next.js application, transfers the build artifact to the target server and starts the application using PM2.

The hosting setup is designed for a server-based deployment in which the Next.js frontend is operated as a Node.js application. Environment-specific configuration is provided through deployment variables and runtime environment variables, in particular for connecting the frontend to the Java Spring Boot backend REST API. The deployment configurations support staged and production-oriented deployment flows and enable the frontend and backend applications to be hosted together. The platform is hosted and processed within the EU and GDPR.

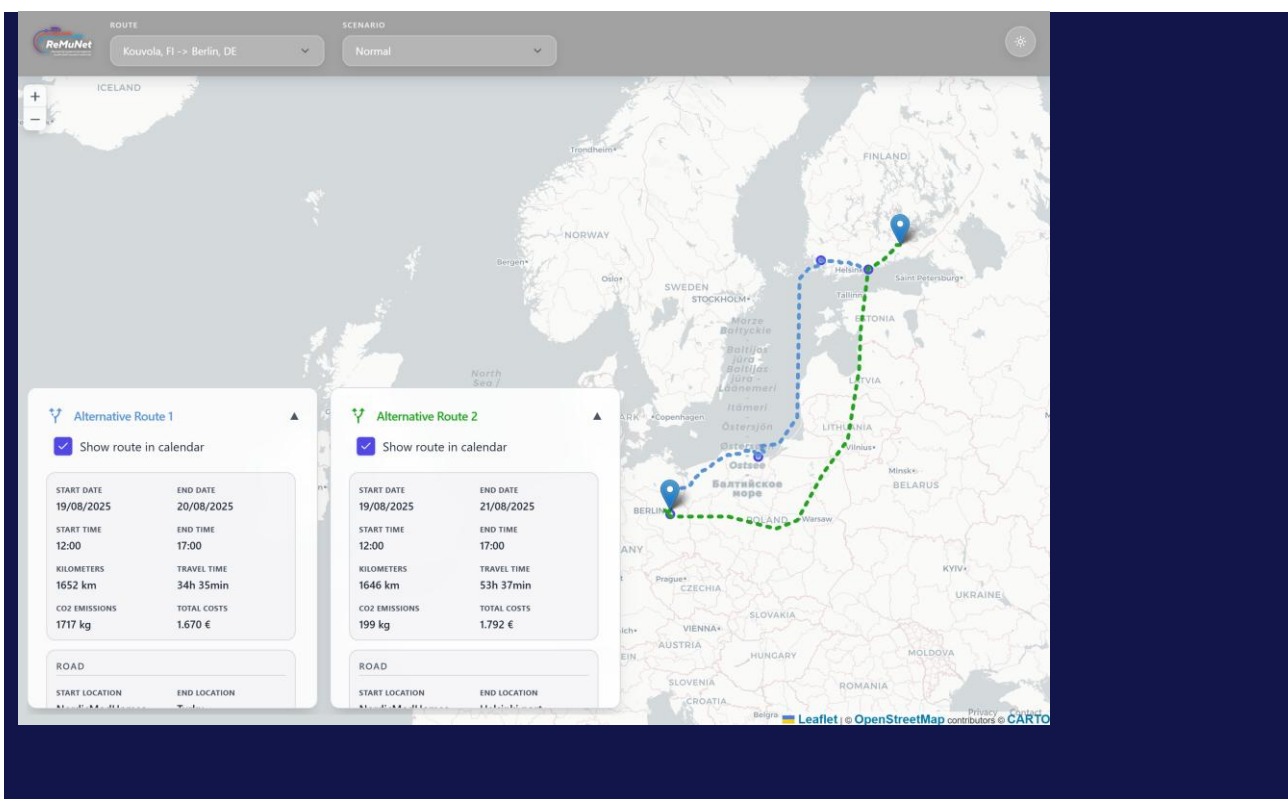
9. Result and Status

The implemented platform provides a functional frontend for viewing and comparing routing scenarios. It enables stakeholders to inspect routing alternatives in a visual and interactive way and supports the evaluation of transport routes under normal and disrupted conditions, presented through a uniform and neutral interface.

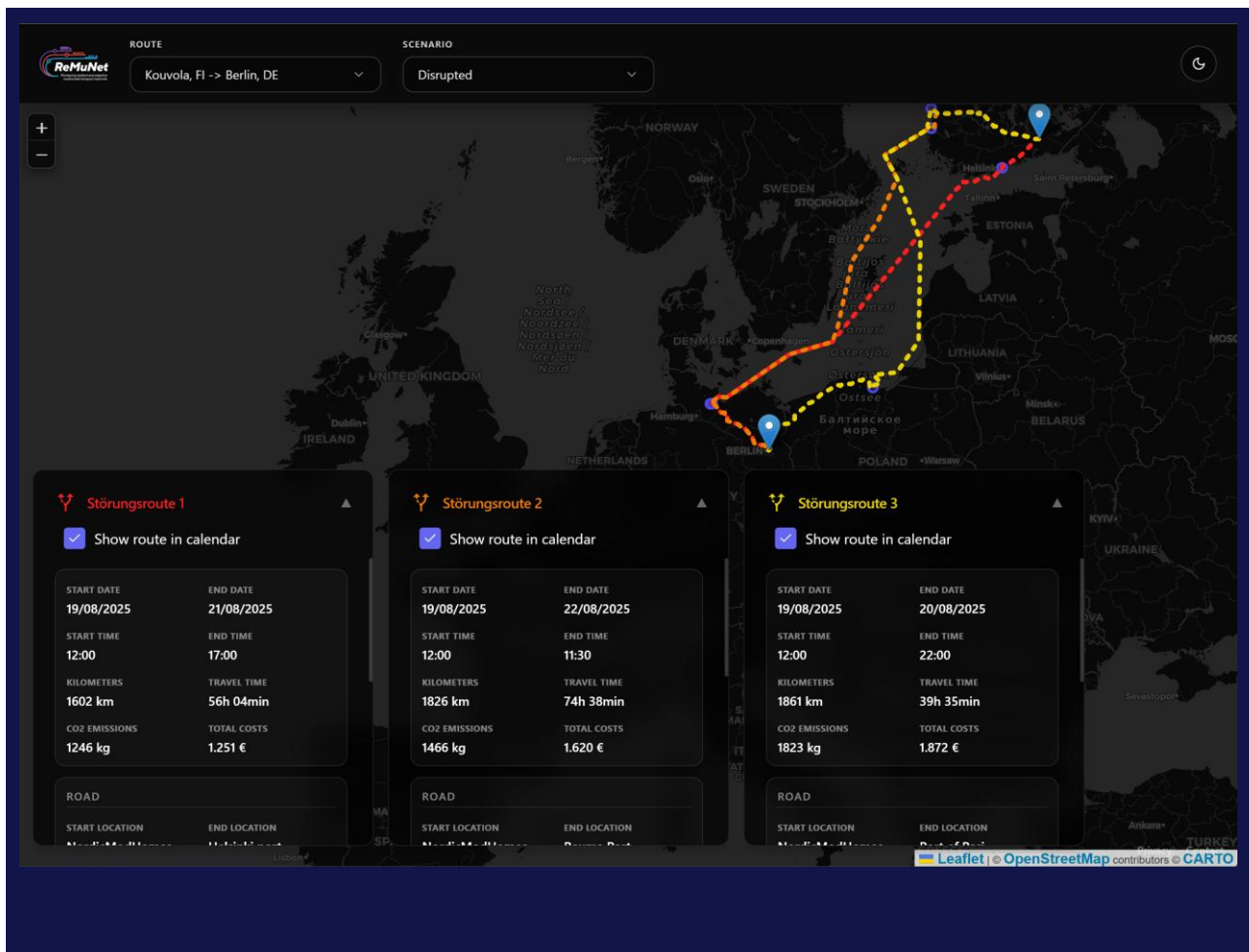
The transport-enquiry and comparison functionality, the map-based visualization, the restricted-territory filtering and the light/dark responsive interface are implemented. The application is prepared for deployment through the existing pipeline setup and can be run locally for development, testing and demonstration purposes.

GUI Example impressions

Normal, non-disrupted routing example in the GUI:



Example of disrupted routing in the GUI. Passing Baltic States is not possible. Alternatives and KPIS presented.



10. Deliverable Scope

This deliverable covers the user-facing visualization of routing results on the frontend. This includes:

- Web-based user interface with a uniform, neutral design.
- Route and scenario selection.
- Map-based route visualization.
- Route comparison and metric display.
- Consumption of the backend routing services (PTV and Mansio) through the REST API.
- Handling of restricted territory filtering on displayed routes.

The deliverable does not implement the routing algorithms themselves. Routing calculations, scenario generation and source transport data are provided by the connected backend services described in deliverable T3.6.

11. Summary, implications, limitations and outlook

11.1 Summary

Deliverable 3.8 has provided the web-based frontend of the ReMuNet routing platform, implemented as a Next.js/React application that consumes the REST API exposed by the Java Spring Boot backend documented in Deliverable 3.7. The frontend retrieves routing scenarios and handover data originating from the integrated PTV routing service and Mansio, filters and transforms this data for presentation, and visualises the resulting transport options on an interactive Leaflet-based map. Users can select between normal

and disrupted routing scenarios, show or hide individual route alternatives, and inspect route comparison cards containing operational indicators such as distance, travel duration, costs and CO2 emissions, together with the individual route legs. The interface offers a uniform, neutral and simple design suited to the European context, supports light and dark display modes, and is responsive across desktop and smaller screen sizes. The application is prepared for deployment through the existing Bitbucket Pipelines setup and can also be run locally for development, testing and demonstration.

11.2 Implications

With Deliverable 3.8, the ReMuNet routing platform is completed end to end: Deliverable 3.7 established the backend integration and orchestration layer and its data model, and this deliverable adds the user-facing layer through which directly and indirectly involved stakeholders actually access and interpret that data. The frontend turns the backend's machine-readable interfaces into a visual, comparative decision-support tool, making routing scenarios, route alternatives and handover information understandable to users regardless of their own IT maturity or familiarity with the underlying technical systems. By presenting normal and disrupted scenarios side by side, together with route-level metrics such as distance, duration, cost and CO2 emissions, the frontend makes the cost and emission trade-offs of different multimodal routes directly visible to logistics operators, transport planners and other operational stakeholders.

This directly supports the wider objectives of the ReMuNet project: a uniform, neutral and simple-to-use interface lowers the barrier for smaller transport companies and SMEs to engage with multimodal route planning, the visual comparison of disrupted versus normal scenarios contributes to a more rapid and informed network response to disruptive events, and the consistent presentation of emission-relevant indicators supports the project's goal of shifting transport towards lower-emission multimodal alternatives. As the platform's point of contact for end users, the frontend is also what ultimately determines whether the technical capabilities built into the backend translate into practical impact for the project's stakeholders.

11.3 Limitations

As defined in the deliverable's scope, the frontend covers the user-facing visualisation of routing results and does not implement the routing algorithms themselves; route calculation, scenario generation and the underlying transport data remain the responsibility of the backend services documented in Deliverable 3.7. The frontend is consequently dependent on the availability, response times and data quality of the backend REST API and, transitively, of the integrated PTV and Mansio services; it cannot compensate for gaps or delays in the data it receives. The application is presently hosted internally rather than on public-facing infrastructure, and the restricted-territory filtering applied to displayed routes means that the visualisation reflects only those routes and tours permitted under the currently configured filtering rules. Finally, in line with its defined scope, the frontend does not provide booking functionality: it supports the inspection and comparison of routing options, while booking and operational execution of transports remain outside the boundaries of this deliverable.

11.4 Outlook

With Deliverables 3.7 and 3.8 in place, the ReMuNet routing platform now provides a complete path from external routing and logistics data to a user-facing, map-based decision-support tool. Going forward, the modular separation between the backend's consolidated data model and the frontend's presentation layer allows the platform to evolve on both sides independently: additional data sources or individual-value queries can be added on the backend without requiring changes to the frontend's consumption logic, while the user interface, comparison views and visualisation features can be refined based on stakeholder feedback without affecting the underlying integrations. As the project continues, this platform is intended to remain the central tool through which directly and indirectly involved stakeholders engage with ReMuNet's routing and disruption information, and to serve as a practical demonstration of how the project's broader objectives around resilience, efficiency and emission reduction translate into an accessible, everyday decision-support tool for the multimodal transport network.