Deliverable D 3.1

ESEP4Freight reference architecture

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Report contributors		
Name	Beneficiary Short Name	Details of contribution
Vivin Kumar Sudhakar	SGKV	Chapters 1,2,3,4,5,7,8, Main Editor
Ben Müller	SGKV	Chapters 5 and 6, Supporting Editor
Francisca Rosell Camps	EUT	Chapter 6
Ismail El Haloui Benkirane	EUT	Chapter 6
Aleix Vila Cano	EUT	Chapter 6.2 - Blockchain Proof of Concept
Javier Gómez	UPM	Chapter 6.2 - Blockchain Proof of Concept
Eric Feyen	UIRR	First internal reviewer
Celestino Sánchez	EURNEX	Second internal reviewer

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Executive Summary

The aim of this deliverable is to define the reference architecture of the ESEP4Freight Web Platform describing the requirements, specifications, and data models. The architecture was defined based on the state-of-the-art analysis of research and innovation projects, review of existing platforms, apart from incorporating the requirements and suggestions of the stakeholders. These analysis and requirements helped to define the framework of the Web Platform and accordingly certain additional data collection actions were initiated apart from those data collected in working packages 1 and 2. These additional data sets include intermodal timetables, benchmark for external cost calculator, and the stakeholder contact information.

Accordingly, the architecture of the Web Platform specifies the technologies for the backend, frontend and the database. For the design and deployment of the architecture, software architecture diagram, a class diagram, use case diagram, and the deployment diagram were created. Moreover, the features of the Web Platform were clearly defined with their objectives and functionalities. Finally, the technical specifications of the architecture comprising of the server specifications and server security were identified. These specifications were further complimented with the development of user stories for the various potential use cases of the platform by the users. The architecture described in this document is a first working version of the architecture and may be accordingly adapted based on new findings or new inputs from the Stakeholder Group. However, no major changes in the architecture are expected.

The report also mentions the challenges encountered in data collection and the mitigation measures adopted based on the recommendations of the stakeholders in designing the architecture. The deliverable also describes the collaboration efforts undertaken with other ER-JU projects like FP5-TRANS4M-R and ADMIRAL. Apart from these, the compliance to the DTLF ontology and Federated requirements, the adoption of FAIR and Open data principles while defining the contours of the Web Platform architecture enabling Interoperability were also explained.

Keywords: Web Platform, Architecture, Technical Specifications, User Stories, Open Data, Interoperability

Abbreviations and acronyms

Abbreviation / Acronym	Description
ADIF	Administrador de Infraestructuras Ferroviarias
ADMIRAL	Advanced multimodal marketplace for low-emission and energy transportation
AG	Aktiengesellschaft
API	Application Programwirming Interface
AS	Aksjeselskap
AT	Austria
BVBA	Besloten vennootschap met beperkte aansprakelijkheid
CFL	Société Nationale des Chemins de Fer Luxembourgeois
CIP	Customer Information Platform
CMR	Convention relative au contrat de transport international de marchandises par route
CO2	Carbon dioxide
CPU	Central Processing Unit
CSS	Cascading Style Sheets
CT	Combined Transport
CTO	Combined Transport Operator
DACH	Germany (D), Austria (A), Switzerland (CH)
DB	Deutsche Bahn
DE	Deutschland
DFDS	Det Forenede Dampskibs-Selskab
DG	Directorate-General
DGG	Deutsche GVZ Gesellschaft
DMP	Data Management Plan
DTLF	Digital Transport and Logistics Forum
DVZ	Deutsche Verkehrs-Zeitung
ER-JU	Europe's Rail Joint Undertaking
ERS	European Rail Shuttle
ESEP	European Shift enabler Portal
EU	European Union
EURNEX	European rail Research Network for Excellence
EUT	Eurecat
FA	Flagship Area
FAIR	Findable, Accessible, Interoperable, Reusable
FAQ	Frequently asked Questions
FENIX	european Federated Network of Information Exchange in logistics

FERRMED	Promotion du Grand Axe Ferroviaire de Marchandises Scandinavie-Rhin-Rhône-Méditerranée Occidentale
GB	Gigabytes
GCA	Groupe Charles Andre
GDPR	General Data Protection Regulation
GIS	Geogrpahic Information System
GSA	Germany, Switzerland, Austria
GVZ	Güterverkehrszentren
HGK	Häfen und Güterverkehr Köln AG
HGV	Heavy Goods Vehicle
HTML	Hypertext Markuo Language
HTTP	Hypertext Transfer Protocol
IGS	Intelligent Global Solutions
IP	Internet Protocol
IT	Infomation Technology
KG	Kommanditgesellschaft
KPI	Key Performance Indicator
KTH	Kungliga Tekniska högskolan
LCV	Light Commercial Vehicle
LKW	Lastkraftwagen
LSP	Logistics Supply Provider
MAWP	Multi-Annual Work Programme
NUTS	Nomenclature of Territorial Units for Statistics
PDF	Portable Document Format
POC	Proof of Concept
RAM	Random Access Memory
RDBMS	Relational Database Management System
REST	Representational State Transfer
RFC	Rail Freight Corridor
RINF	Registers of Infrastructure
RNE	RailNetEurope
SA	Société anonyme
SGKV	Studiengesellschaft für den Kombinierten Verkehr
SPA	Single Page Application
SQL	Structured Query Language
SSH	Secure Shell
SSL	Secure Sockets Layer
SUT	Schifffahrt und Technik
TEN-T	Trans-European Transport Network

TFG	Transfracht Gesellschaft
UIR	Unione Interporti Riuniti
UIRR	International Union for Road-Rail Combined Transport
WP	Working Package
WTT	Well-to-Tank

1 Background

The present document constitutes the Deliverable D3.1 “ESEP4Freight reference architecture” in the project European Shift Enabler Portal for Freight (ESEP4Freight). Funding body is the EU-RAIL in the call HORIZON-ER-JU-2022-02.

In the future European mobility system, rail freight plays a key role in making a significant contribution to achieving the goals of the European Green Deal. The fastest and most efficient way to decarbonize freight transport is to shift freight to rail. To achieve this shift, the overall competitiveness of rail in the transport market should be improved. To strengthen the role of rail freight in the transportation market, it is necessary to attract the attention of freight customers. An approach to increase the awareness of rail freight is to provide customers with high-quality and open information about the possibilities of rail transport and the associated benefits of intermodal rail freight.

The objective of the ESEP4Freight project is therefore to provide freight customers with an overview of the available intermodal rail freight services in Europe. This will be supported by the creation of a Web Platform based on an existing map developed by SGKV, along with the identification of freight flows with a higher potential for transport by rail. The Web Platform will include an interactive map with different modules such as an external costs calculator, a schedule viewer, a route viewer, a contract toolbox and a match making tool. The aim of task 3.1 in work package 3 is to gather the system requirements and specifications to be able to design the proper reference architecture to materialize the web-based map platform and the back-end processes and data exchange connectors to enable interoperability for the platform.

2 Objectives

This document comprises the output of T3.1 and has been prepared to provide the definition of the reference architecture describing the requirements, specifications and data models to build the ESEP4Freight web-based platform. The objective of this work package is to develop a Web Platform that provides centralized high-quality information and simplifies the realisation of intermodal supply chains. The specific objectives of the work package are as follows:

- To create a service-oriented platform to host the myriads of services to support the shift to cleaner transport modes for freight consisting of a central repository and APIs to serve the distinct modules and the web-based graphical user interface
- To develop an interactive map-based visualisation, with static periodic update possibilities, of the rail freight network in Europe including the terminal location and contact data, their infrastructure, services, and schedule information
- To produce a CO_2 calculator module to estimate the reduction of emissions from shifting to rail and/or inland waterway based intermodal transport supply chain on relevant corridors
- To build a visualisation of Origin-Destination routes module with high growth potential segments estimated based on KPIs along with First and Last mile information for specific regions
- To produce a set of model harmonised contracts module for shifting from one mode of transport to another along with legal conditions, that serves as a reference to the supply chain planners and managers
- To develop an add-on module hosted in the service-oriented platform to enable different actors to create profiles and market their services like match making between shippers, forwarders, railways service providers, infrastructure managers, and other institutions in the freight intermodal transport with an option to submit information directly by the actors on the platform.
- To integrate a proof-of-concept connection to e-CMR and blockchain existing platforms to train and disseminate among stakeholders the usage of this mechanism to enhance trust in intermodal supply chains

The aim of the first task of WP3 (T3.1) is to gather the system requirements and specifications to be able to design the proper reference architecture to materialize the web-based map platform and the back-end processes and data exchange connectors to enable interoperability for the platform to be tested in the pilots in work package 4. Inputs from the rail freight services mapping performed in work package 1 and the recommendations for the implementation of smart contracts from work package 2 will be considered in the architecture design. Furthermore, the requirements for the CO_2 calculator, visualisation of the high potential Origin-Destination routes, schedule viewer and match making platform will also be specified. The process of requirements gathering will be synchronized with the activities envisioned in work package 4 for the Pilot and work package 5 for the Stakeholder’s Group, since they will be the main users and contributors respectively. Besides a thorough analysis will be performed to select the data model for the information representation to ease interoperability and to cover gaps for the implementation of the business cases. The proposed open web-based map tool within ESEP4Freight will be interoperable by design to reach a high mark in the interoperability maturity score. It will follow harmonic approaches, in particular linked to Registers of Infrastructure (RINF), Primary and Subsidiary location codes, Rail Facility Portal and the FEDeRATED/FENIX projects supporting DTLF. The potential for integration of interfaces resulting from the EU-Rail FA 5 Call HORIZON-ERJU-FA5-01 will also be considered. Besides, it will not make use of proprietary software tools that might hinder open Internet and interoperable data models. Finally, special attention will be paid to follow the FAIR principles[1] to maximise the potential of digital solutions for the single market.

The creation of the Web Platform, with D3.1 as its first step, is expected to primarily contribute, at a high-level, to the second cluster of the FA5, “Seamless rail freight” as described in the Europe’s Rail JU Multi-Annual Work Programme (MAWP). The Web Platform is developing an online portal providing relevant information on the European rail freight system. The goal is to position the Web Platform as the reference tool for stakeholders in the logistics chain seeking high-quality information on the possibilities of modal shift to rail. Information about rail schedules, potential transport flows between regions, and information about the available infrastructure are expected to play a centra role in targeting the appropriate audience. The Web Platform would serve in this manner as gateway to promote and facilitate the use of advanced tools developed in the “Seamless rail freight” cluster from FA5, such as multimodal journey planner with dynamic information or booking features.

[1] https://www.openaire.eu/how-to-make-your-data-fair

3 State of the art

3.1 Research and innovation projects

A range of ongoing research and innovation projects was analysed as the state of the art for the development of the ESEP4Freight Web Platform architecture. In certain cases, collaboration with some of the projects were enabled by the partners of ESEP4Freight. A summary of such research and innovation projects considered are as follows:

The CO_2 estimation tool developed as a part of the **SYSLOG** project by SGKV enables users to design several types of transport chains between specific origins and destinations to calculate their CO_2 emissions. It allows users to visualize the benefits of modal shift from the emissions perspective with a simple and interactive tool[2]. SGKV, as the developer of the tool in SYSLOG project, transferred the knowledge as the foundation for the planned CO_2 / External costs calculator module in the Web Platform.

The feasibility study **EiFa** aims at making it easier for the actors and customers to exchange information on intermodal transport routes and timetables. A uniform timetable structure was designed for the rail and waterway/short sea modes of transport. This uniform structure represents an important basis for digitalisation and increasing transparency in intermodal transport[3]. The uniform timetable structure developed in this study served as the basis for the schedule viewer in the Web Platform. SGKV as lead partner and UIRR as participant of the EiFa project transferred the knowledge and results into the project to extend the standardisation and transparency created at the country level (Germany) to the European level.

The project **FRONTIER** developed, applied and tested autonomous management systems, secured by design, that constantly evolve using data generated from real-time monitoring of the transportation system, knowledge generated by operators and decision makers, and simulation models providing system optimal solutions accounting for new mobility services and technologies[4]. Project partner Eurecat employed their experience with respect to intermodal solutions, transport ontologies, and data formats harmonisation in this project for the architecture development.

The project **RIDE2RAIL** integrated multiple (public, private and social) data sets and sources and existing platforms to promote an effective Ride Sharing practice of citizens, making it a complementary transport mode that extends public transport and rail networks. It presents a set of validated proof of concepts and business cases envisaging future mobility scenarios, where advanced transport solutions were seamlessly integrated into existing collective transport services [5]. Background on data analysis of different route alternatives and platforms interoperability learnt during the project was the starting point for project partner Eurecat for identifying the tools for

[2] https://syslog.plus/
[3] https://sgkv.de/portfolio/projekte/eifa/
[4] https://www.frontier-project.eu/
[5] https://ride2rail.eu/

the architecture design and for the functions to be developed.

The project **FP5-TRANS4M-R** will develop, amongst other results, tools for dynamic specific information about rail and multimodal services[6]. KTH, as member of FP5-TRANS4M-R, has been actively liaising with the complementary project to ensure outputs and results in terms of the identification of high potential routes and the best methodologies and KPIs will allow smooth interoperability for the employment of multimodal freight services tools.

ADMIRAL is a project aiming to transform supply chain management in freight transportation by developing a cutting-edge digital marketplace for multimodal logistics. It will develop a digital marketplace incorporating the whole supply chain to connect logistics service providers and buyers, thereby simplifying cooperation. The marketplace will offer services, digital and cover sea, port and hinterland operations. It will allow buyers, e.g. cargo owners, to select a provider based on information such as delivery times, associated emission levels and service costs. This will enable companies to optimise transport and logistics processes, including emissions throughout the supply chain, even across different countries, and also adds to the resilience of supply chains as one user or application can be easily replaced in case of a disruption[7]. Consultations were carried out with this project with the perspective of the Match making tool, through the project partner UPM.

FEDeRATED is working towards the development of a validated Masterplan for an EU federated network of platforms and a prototype of a data sharing environment for business and public sector use[8]. A review of FEDeRATED recommendations was made to ensure that interoperability principles were embedded in the Web Platform architecture.

3.2 Existing platforms

While there are many options or planning a personal trip across Europe, the situation is not the same when trying to find a map for the whole European railway network, especially for freight purposes. It gets even harder to find an interactive map including all transport modes (railway, road, sea, inland waterway). Nonetheless, there are some initiatives that have put efforts on covering this gap, which were also studied closely during the architecture definition phase. A short overview of the platforms along with potentials for the ESEP4Freight platform are listed below, along with a tabulated overview (Sánchez Martín et al. 2024) of their managing organisation, information availability, and other features relevant from the perspective of the Web Platform.

- **European Transport Maps**: Map based visualization of the terminals with the basic location and contact information. Company and connection details are also available for a particular node and not integrated with each terminal[9]

[6] https://projects.rail-research.europa.eu/eurail-fp5/
[7] https://www.admiral-project.eu/
[8] https://www.federatedplatforms.eu/
[9] https://www.europeantransportmaps.com/

- **Open Transport Map**: Map of road network in the European Union that permits users to visualize the traffic volumes and make routings on the road network. It does not focus on other transport modes[10]
- **Open Sea Maps**: Open-source nautical chart with information like beacons, buoys, port information, and repair shops for navigational support purposes. It also does not focus on other modes of transports[11]
- **Rail Facilities Portal**: Information on rail facilities in Europe such as freight terminals, marshalling yards, maintenance facilities and fuelling stations. But it does not display the connection between facilities or intermodal possibilities with other transport modes[12]
- **RailFreight EU Terminal Map 2022**: Limited print and downloadable visualization of the rail freight terminals in the EU based on the rail facilities portal. It does not contain any additional information apart from the visualization itself and also lacks other transport modes[13]
- **AGORA Intermodal Terminals in Europe**: Map of intermodal terminals in Europe with contact and basic information on their infrastructure and services. It lacks connection and first/last mile information[14]
- **SGKV Intermodal Map**: Comprehensive representation of Combined Transport (CT) terminals (Bimodal and Trimodal) in Europe and beyond. It contains a range of information such as the contact details, handling equipment, terminal services, CT connections, first/last mile providers among other things and is also completely free of charge. However, the completeness of data is very high for the DACH region compared to the whole of Europe (and world)[15]
- **Route Scanner**: It is a platform that allows the transport operators to publish their schedules for container transports. It enables shippers and freight forwarders to find door to door and completely neutral services, with optimised routes, CO_2 emissions and costs. However, it is a freemium solution[16]
- **Study of traffic and modal shift optimization**: This is a report by FERRMED that identified freight traffic by modality and also on the main corridors in Europe. It focuses on identification of traffic, rail actions for modal shift apart from the aspects of rolling stock and environmental impacts in the form of a report[17]

[10] https://opentransportmap.info/
[11] https://www.openseamap.org/
[12] https://rne.eu/it/rne-applications/rfp/
[13] https://www.railfreight.com/railfreight/2021/11/11/railfreight-presents-the-eu-terminal-map-2022/?gdpr=deny
[14] https://www.intermodal-terminals.eu/
[15] https://www.intermodal-map.com/
[16] https://www.routescanner.com/
[17] https://ferrmed.com/wp-content/uploads/2023/06/15_50_2_Bassas.pdf

- **RNE-CIP**: It is a platform that provides information such as routing, terminals, track properties, and infrastructure investment options to railway undertakings. It is a multi-corridor tool enabling re-routing within participating rail freight corridors. For the infrastructure managers and the rail freight corridors, the tool can be used for project management. But it is an operational planning tool for stakeholders and not an information portal that can promote modal shift[18]
- **TENtec Interactive Map Viewer**: It is a map that allows to view different sections and elements of the TEN-T network, along with the representation of the infrastructure data and other properties. It is standalone representation of the corridors and does not consider other entities of the transport chain[19]

Table 1 Existing platforms, Source: Sánchez Martín et al., 2024

Platform / Tool name	Publisher/ Manager	Information on transportation services	Information on infrastructure	Other relevant features
European Transport Maps	Baltic Press	Yes (mainly maritime)	No	Commercial tool
Rail Facilities Portal	UIRR/RNE	No	Only terminals (focus on rail)	Comprehensive information on terminals
Intermodal Terminals	KombiConsult	No	Only terminals	-
Intermodal Map	SGKV	Yes (only in a few cases)	Only terminals	-
Route Scanner	Route Scanner	Yes (comprehensive selection)	No	Commercial tool Offers an API Estimated time of transport and CO_2 emissions of routes
Study of traffic and modal shift optimization	FERRMED	No	Yes (mainly RFC corridors), no terminals	Additional information on transported volumes
RNE-CIP	RNE	No	Yes (mainly RFC corridors), basic information on terminals	Tools for routing planning
TENtec Interactive Map Viewer	DG Move	No	Yes (comprehensive for infrastructure networks)	Comprehensive information on TEN-T infrastructure

[18] https://rne.eu/it/rne-applications/cip/what-is-cip/
[19] https://webgate.ec.europa.eu/tentec-maps/web/public/screen/home

3.3 Relevance to ESEP4Freight

Most of projects and platforms focus only on a specific transport mode making it challenging to find the best intermodal transport solutions. One big challenge that has been observed is the consolidation of information from multiple data sources, some of which are openly available, while most others are not. Besides this, the data format and updating also needs adequate attention. Therefore, the architecture definition as a part of this work package was aligned to overcome these challenges to build a Web Platform for decision support. Being aware of the challenges and the mandate from the EU to foster the shifting towards cleaning transport modes for freight, specifically to rail, ESEP4Freight aims at developing a Web Platform with focus on Europe by integrating new services such as a schedule viewer, a CO_2 calculator, a route viewer, a contract toolbox and a matchmaking tool. In this approach, the Web Platform would provide a single point support to the supply chain transport planners across Europe that enables them to shift towards sustainable intermodal transport.

4 Framework for the Web Platform

The basic framework of the Web Platform as envisaged in the grant agreement of the project consisted of the following modules.

1. Interactive map with infrastructure data
2. Corridor viewer
3. CO_2 calculator
4. Route viewer
5. Contract toolbox
6. Matchmaking tool

Within this framework, the data collection for realising these modules was based on the SGKV Intermodal Map and complementing it with additional information or layers. However, there were considerable challenges associated with data collection due to varying quality and availability across Europe. Hence, the following levels of data have been defined. The Standard level comprises data across Europe (as far as data are available) and the Advanced level considers the TEN-T corridors as its basis. The data sets were refined at the beginning of the project based on the research, the interest of the companies, and institutions involved in the Stakeholders Group.

Standard level (across Europe):

- Data on intermodal terminals such as:
  - Location
  - Opening times
  - Transport modes
  - Infrastructure (tracks, parking, storage, technologies)
  - Basic services
- Type of rail freight services among terminals
- Recommendations for a harmonised contractual framework: Combined Transport Operators (CTOs) with CT customers and CTOs with Logistic Supply Providers (LSPs) / Shippers
- CO_2 consumption based on basic parameters (e.g. distance and transport mode)
- Information for the Matchmaking module for all intermodal actor categories across Europe such as Company name and web

Advanced level (for specific areas or corridors):

- Added value intermodal services (extra services like customs, brake testing)
- Connection schedules from the most important intermodal transport operators
- Information for the route viewer module based on KPIs for specific areas or corridors, for example the clearance gauge for semi-trailer transportation
- Cargo flows highlighting those with higher potential for modal shift

With this data basis, the framework of the Web Platform was further defined considering the requirements of the market players in the Stakeholder Group. The following were the requirements and recommendations of the Stakeholders that shaped the current status of the Web Platform framework.

- **Overall goals of the Web Platform**: Maintain a clean platform without any outliners based on the availability of data and be representative of the market to promote modal shifts from new players to intermodal transport. In this regard, showcasing some examples for pure road transport and intermodal transport based on some existing connections could be an added value.
- **Target groups and data providers:** Shippers and logistic service providers were suggested as the primary target groups for the platform. From the perspective of the shippers, the KPI requirements are the availability of services, transit times (optional), and estimated range of costs (optional). The supplier of these data would then be the intermodal operators and the logistic service providers in certain cases.
- **First and last mile services**: Suggestion to use map services to showcase possibilities from the location of the shipper or customer would be helpful given the challenges in collecting the actual services data. For example, a visualization of a specific radius around the shipper or customer location with the terminal locations or pointers can be extremely helpful for identifying the CT possibilities. Based on this and the terminal contact data, it can help to find first/last mile services instead of showing a list of truck companies.
- **Technical infrastructure information**: All stakeholders have a unanimous suggestion that the technical information from the intermodal network or the terminals infrastructure are not required for such a Web Platform. However, the profile information of specific rail sections was highlighted as the only key information for transporting semi-trailers.
- **CO_2 calculation module**: It was proposed by the stakeholders to use the default industry average values as the reference for the calculations.
- **Match making module**: This module was envisaged to be a repository of contact information for different stakeholders across various regions of Europe. Moreover, it may also include a comparison of a selection of terminals, related to their location or criterion-like connections, terminal services, transport services, among others. Similarly additional resources like the TEN-T work plan or status reports were suggested to be added here for the users.

Based on these requirements and suggestions shared by the industry stakeholders and the corresponding research by the project team, the framework of the Web Platform was adapted as follows.

The list of modules and their key contents are introduced here.

1. **Interactive map**: Network and terminal infrastructure data, Terminal services
2. **Corridor viewer**: TEN-T corridors, TEN-T documentations, High potential corridors for modal shift
3. **Route viewer**: Connection schedules for the main transport leg, Origin-Destination search
4. **External costs calculator**: Industry normalised values based on the Version 2019 – 1.1 of the 'Handbook on the external costs of transport' from the European Commission (European Commission: Directorate-General for Mobility and Transport 2020)
5. **Contract toolbox**: State of the art with documents repository, recommendations, and Blockchain proof of concept
6. **Matchmaking module**: Directory of contacts, Terminal comparison tool

Apart from these modules, the framework of the Web Platform also envisages a set of general sections like About the project, Public deliverable reports, User handbook, Frequently Asked Questions, Testimonials, Contact form, Terms and Conditions, and Privacy Notice. A detailed description of the data collection for the respective modules and the contributions from other working packages to the Web Platform has been included in the deliverable report D1.2 'Data collection' (Djordjevic et al., 2024). Furthermore, integration possibilities were explored with other ER-JU projects FP5-TRANS4M-R and ADMIRAL. However, it has been mutually concluded that no integration is currently expected.

Furthermore, the architecture of the Web Platform based on this broad framework was planned to follow the federative architecture requirements from the DTLF ontology. The principles of Plug and Play, Technology independent infrastructure services, Federation, and Trust, safety and security were adopted. To ensure plug and play, the architecture is defined to be user (stakeholder) centric, inclusive, open access, intuitive and add value to the market. The architecture would also enable integration of supporting services, apart from aspects of extendibility and technology independence. Meanwhile, Federation is expected to be achieved by providing autonomy to the data providers with differentiation of their services, at the same pursing a collaborative approach to amalgamate the data for representation on the Web Platform. The security aspect has also been considered in the server specifications, to ensure a robust infrastructure, a trusted data storage and exchange environment with resilience (Fanti et al., 2020).

5 Additional data collection

Additional data collection has been initiated to support the three modules redefined based on the developmental process within the project and the discussions with the stakeholders. These are intermodal timetables, benchmark for the external cost calculator, and stakeholder contacts for the Schedule viewer, External costs calculator, and the Stakeholders directory modules respectively. Since these data collection requirements were identified during the project execution phase in addition to the planned data collection documented in deliverable D1.2, the process is expected to be completed by project month 18, before Web Platform validation. An overview of the additional data collection is captured in the following three sub-sections.

5.1 Intermodal timetables

The intermodal timetables would be collected on the basis of the Uniform Timetable format created in the feasibility study EiFa by the project partner SGKV, together with the major intermodal operators in Europe. This template was already introduced in section 5.1 of the deliverable report D1.2 'Data Collection' (Djordjevic et al. 2024).

Furthermore, the timetable data is attempted to be collected from the following major intermodal operators in Europe. The list of intermodal operators has been prepared by combining the market overviews published in industry magazines SUT (Harder 2022) and DVZ (Cordes 2023), apart from desktop research (for freight ferry operators). A combination of desktop research and direct contact with the operators are being conducted in parallel to the development of the Web Platform.

- Adria kombi d.o.o, Slovenia
- Ambrogio GmbH, Germany
- AS Baltic Rail, Estonia
- AT.Intermodal GmbH, Austria
- Bertschi AG, Switzerland
- Bohemiakombi spol.s.r.o, Czech Republic
- BoxXpress.de GmbH, Germany
- CargoBeamer intermodal operations GmbH, Germany
- Cargonet AS, Norway
- CFL intermodal, Luxembourg
- Contargo GmbH & Co. KG, Germany
- Cross-Limits Logistics B.V., Netherlands
- DB Cargo Eurasia GmbH, Germany
- Delcatrans BVBA, Belgium
- DFDS Rail GmbH, Germany
- DHL Global Forwarding, Freight, Germany
- Emons Container Service GmbH, Germany

- ERS Railways GmbH, Germany
- Eurogate Intermodal GmbH, Germany
- European Cargo Logistics GmbH, Germany
- European Gateway Services, Netherlands
- Far East Land Bridge Limited, Austria
- Finnlines Plc., Finland
- Gartner Transportholding GmbH (Gatner KG), Austria
- Green Cargo, Sweden
- Greenmodal Transport Filiale du Groupe Charles Andre (GCA), France
- Hannibal S.p.A., Italy
- Hellmann Worldwide Logistics Germany GmbH & Co. KG, Germany
- HGK Logistics and Intermodal, Germany
- Hupac Group, Switzerland
- Hutchison Ports Europe Intermodal, Netherlands
- IGS Intermodal Container Logistics GmbH, Germany
- Kombiverkehr GmbH & Co. KG, Germany
- Konrad Zippel Spediteur GmbH & Co. KG, Germany
- Lineas Intermodal, Belgium
- LKW Walter Internationale Transportorganisation AG, Austria
- Locon Logistik & Co. Consulting AG, Germany
- Mercitalia Intermodal S.p.A., Italy
- Metrans a.s., Czech Republic
- Move Intermodal nv, Belgium
- Naviland Cargo, France
- Necoss Neutral Container Shuttle System GmbH, Germany
- Neska Intermodal GmbH, Germany
- Nordliner Gesellschaft für Eisenbahnverkehre mbH, Germany
- Nosta Rail GmbH, Germany
- Novatrans S.A., France
- Optimodal Nederland B.V., Netherlands
- PCC Intermodal S.A., Poland
- Primerail GmbH, Germany
- P&O Ferrymasters, Europe
- Railcare AG, Switzerland
- Rail Cargo Group, Austria
- Raillogix B.V., Netherlands
- RAlpin AG, Switzerland
- Rocombi SA, Romania

- Roland Spedition GmbH, Austria
- Roland Umschlagsgesellschaft für Kombinierten Güterverkehr mbH. & Co. KG, Germany
- Samskip, Netherlands
- Scandlines Deutschland GmbH, Germany
- Schweizerzug AG, Switzerland
- Shenker DE/Shenker Europe/Full Load Solutions, Germany
- Societa Alpe Adria S.p.A., Italy
- Spedition Weets GmbH, Germany
- Stena Line Scandinavia AB, Sweden
- T3M, France
- TFG Transfracht GmbH, Germany
- TT-Line GmbH & Co. KG, Germany
- TX Logistik AG, Germany
- VIIA, France
- Wenzel Logistics GmbH, Austria

An example of the timetable data collected based on the information published on the website of the intermodal operator Hupac[20] in the EiFa format[21] is as follows in Figure 1:

Timetable valid from Date	Timetable valid until Date	UIRR Code Origin Terminal	Name of Origin Terminal	Origin Country	UIRR Code Destination Terminal	Name of Destination Terminal	Destination Country	Closing for LU at Origin Terminal [Days]	Closing for LU at Origin Terminal [Time]	Days of Departure from Origin Terminal	Provision of LU at Destination Terminal [Day]	Provision of LU at Destination Terminal [Time]	Clearance Gauge for Railway Network	CT Operator Name	CT Operator RICS Code	CT Operator Contact Person Name	CT Operator Contact Phone Number	CT Operator E-Mail Address	CT Operator Web Link	Others
11122022	9122023	12	ANTWERP COMBINANT	BE	561	DUISBURG RHEINHAUSEN DIT	DE	A	14:00:00+01:00	1000000	B	08:00:00+01:00	C70 C400 P400	HUPAC INTERMODAL	3846		41588558800	info.de@hupac.com	https://www.hupac.com/	
11122022	9122023	12	ANTWERP COMBINANT	BE	561	DUISBURG RHEINHAUSEN DIT	DE	A	14:00:00+01:00	1000000	B	08:00:00+01:00	C70 C400 P400	HUPAC INTERMODAL	3846		41588558800	info.de@hupac.com	https://www.hupac.com/	
11122022	9122023	561	DUISBURG RHEINHAUSEN DIT	DE	12	ANTWERP COMBINANT	BE	A	15:00:00+01:00	1000000	B	05:30:00+01:00	C70 C400 P400	HUPAC INTERMODAL	3846		41588558800	info.de@hupac.com	https://www.hupac.com/	

Figure 1 Hupac Timetable. SGKV, 2024

5.2 Benchmark for external costs calculator

The external cost calculator component of the Web Platform will be based upon Version 2019 – 1.1 of the 'Handbook on the external costs of transport' from the European Commission (European Commission: Directorate-General for Mobility and Transport 2020). The handbook proposes external costs based on seven different categories and gives average values for costs in €-cents either per tkm (tonne-kilometer) or vkm (vehicle-kilometer).

The first external cost category is accident costs (Table 2) in which Freight transport is divided into Light Commercial Vehicles, Heavy Goods Vehicles, Freight Trains and Inland Vessels.

[20] https://www.hupac.com/EN/Shuttle-Net-Timetable-a71f6000
[21] https://sgkv.de/portfolio/projekte/eifa/

Table 2 Accidents costs. Source: Handbook on the external costs of transport (European Commission, 2021)

Freight transport	Billion €	€-cent per tkm	€-cent per vkm
LCV	19.8	6.0	4.1
HGV	23.0	1.3	15.5
Freight train	0.3	0.1	34.1
Inland Vessel	0.1	0.1	86.3

The average air pollution costs (Table 3) are further broken down into LCV based on Petrol and Diesel, HGV, Electric and Diesel based Freight trains and Inland vessels.

Table 3 Air pollution cost. Source: Handbook on the external costs of transport (European Commission, 2021)

Freight transport	Billion €	€-cent per tkm	@-cent per vkm
LCV	15.49	4.68	3.24
LCV – petrol	0.33	1.72	1.17
LCV – diesel	15.16	4.86	3.37
HGV	13.93	0.76	9.38
Freight train electric	0.01	0.004	2.14
Freight train diesel	0.66	0.68	305.39
Inland Vessel	1.93	1.29	1.869

The average climate change costs (Table 4) are likewise provided for LCV for Petrol and Diesel, HGV, Diesel Freight trains and Inland vessels.

Table 4 Climate change costs. Source: Handbook on the external costs of transport (European Commission, 2021)

Freight transport	Billion €	€-cent per tkm	€-cent per vkm
LCV	13.17	3.98	2.75
LCV – petrol	0.71	3.76	2.56
LCV – diesel	12.45	3.99	2.77
HGV	9.63	0.53	6.48
Freight train diesel	0.24	0.25	112.4
Inland Vessel	0.40	0.27	383.1

For the average costs of noise (Table 5) there are values for LCV, HGV is classified by weight and Freight trains by Electric or Diesel.

Table 5 Cost of noise. Source: Handbook on the external costs of transport (European Commission, 2021)

Freight transport	Billion €	€-cent per tkm	€-cent per vkm
LCV	5.4	1.6	1.1
HGV 3.5 – 7.5 t	1.0	1.2	4.0
HGV 7.5 – 16 t	1.8	0.8	5.7
HGV 16 – 32 t	3.0	0.4	6.5
HGV > 32 t	3.2	0.4	7.2
Freight train electric	2.1	0.6	359
Freight train diesel	0.4	0.4	201

Average congestion costs (Table 6) are only provided for LCV and HGV and differ between urban and inter-urban areas.

Table 6 Congestion costs. Source: Handbook on the external costs of transport (European Commission, 2021)

Freight transport	Total EU28 (Billion €)	€-cent per tkm	€-cent per vkm	Total EU28 (Billion €)	€-cent per tkm	€-cent per vkm
LCV	38.5	11.63	8.05	6.6	2.01	1.39
LCV – urban	32.6	27.75	19.21	5.6	4.78	3.31
LCV – inter-urban	5.9	2.78	1.92	1.0	0.48	0.33
HGV	23.8	1.30	17.72	3.8	0.21	2.81
HGV – urban	17.6	3.81	51.94	3.1	0.67	9.11
HGV – inter-urban	6.2	0.45	6.20	0.7	0.05	0.69

Well-to-tank emission costs (Table 7) are provided for every mode of transport. Diesel and Petrol LCV, HGV, electric and diesel Freight trains and Inland vessels.

Table 7 WTT emission costs. Source: Handbook on the external costs of transport (European Commission, 2021)

Freight transport	Billion €	€-cent per tkm	€-cent per vkm
LCV	3.79	1.15	0.79
LCV – petrol	0.22	1.18	0.81
LCV – diesel	3.57	1.14	0.79
HGV	3.71	0.20	2.50
Freight train electric	0.50	0.16	86.5
Freight train diesel	0.13	0.14	61.3
Inland Vessel	0.20	0.13	191.4

Finally, the average costs of habitat damage (Table 8) are given for LCV, HGV, electric and diesel trains as well as Inland Vessels.

Table 8 Habitat damage costs. Source: Handbook on the external costs of transport (European Commission, 2021)

Freight transport	Billion €	€-cent per tkm	€-cent per vkm
LCV	4.4	1.35	0.9
HGV	3.6	0.19	2.4
Freight train electric	0.8	0.24	134
Freight train diesel	0.2	0.25	111
Inland Vessel	0.30	0.20	2.9

Based on these values, the system will be able to calculate average external transport costs based on routes chosen by the user. The biggest challenges for this module will be to differentiate between urban and inter-urban route sections and to differentiate between electric and diesel fuelled freight trains.

5.3 Stakeholders' directory

The Stakeholders' directory is planned as a repository of intermodal stakeholders from the broad spectrum of the transport chain encompassing different regions of Europe. It is envisaged to provide the users the contact information for different categories of stakeholders. For this purpose, the names of the stakeholders and their contact information would be sourced from the various industry associations and online portals like in the following listed examples.

- Italian region: UIR-Unione Interporti Riuniti
- DACH region: SGKV-German Research Association for Combined Transport
- Spanish region: Port of Barcelona and ADIF-Administrador de Infraestructuras Ferroviarias
- Europe: UIRR-International Union for Road-Rail Combined Transport and DGG-Deutsche GVZ-Gesellschaft
- Online-Portal: https://railmarket.com/eu

A representative image (own visualisation by SGKV) for this directory is shown in Figure 2. On selecting the type of stakeholder and the region, the users would be able to see the list of stakeholders and their contact information (link to their homepages as in this example image).

Figure 2 Stakeholder directory and details – A reference. SGKV, 2024

6 Architecture of the Web Platform

The ESEP4Freight Web Platform is a comprehensive system designed to provide advanced intermodal logistics solutions in Europe. As described in Section 6, the Web Platform offers two levels of data:

Standard Level (across Europe): This level comprises basic data about intermodal terminals, such as location, transport modes, capacities, infrastructure, opening hours, safety conditions, basic services, and cargo flows between terminals. It also includes information about rail freight services, as well as a common legal and contractual framework.

Advanced Level (for specific areas or corridors): This level provides additional detailed information, such as value-added services, connection schedules with major intermodal transport operators, infrastructure constraints, network information, and optimization criteria. Additionally, it provides more detailed data on CO_2 consumption based on specific parameters.

The technical documentation of the ESEP4Freight platform is exclusively intended for web developers. Its purpose is to provide a comprehensive guide on the technologies used, architecture diagrams, and user interface mock-ups. It is designed to facilitate understanding and efficient development of the platform, enabling developers to implement new features, maintain the system, and effectively troubleshoot technical issues. This documentation will serve as an essential resource for the development team, providing a clear and complete reference of all technical aspects of the platform.

6.1 Technologies

6.1.1 Backend

Python: is known for its simplicity and readability, which makes it a powerful and versatile programming language.

Django: is framework with strong features, scalability, quick development and practical design with a high level of abstraction. It offers a variety of tools and features that simplify the development process.

Node.js: It will be in a separate Docker service as a module (Proof of concept for block chain – smart contracts), and it will connect with the system through endpoints.

API RESTful: for communication between the frontend and the backend.

PostgreSQL: is a reliable and robust open-source RDBMS with advanced features. We plan to utilize PostGIS extension as a spatial database extender for PostgreSQL, enabling storage, querying, and manipulation of geographic objects in the database. PostgreSQL now includes enhancements for geographic objects and functions.

Python, Django, a RESTful API, and PostgresSQL together provide a potent and well-suited toolkit for building contemporary and scalable web applications.

PostgreSQL has PostGIS extension as a spatial database extender, that gives the basis for executing personalized routing solutions. Programmers have the option to utilize the spatial information saved in PostGIS tables in combination with external routing libraries or services to determine pathways across a map.

6.1.2 Frontend

HTML, CSS and JavaScript: for user interface development.

Angular: popular open-source front-end web framework maintained by Google and a community of developers. It is designed to simplify the development and testing of single-page applications (SPAs) and dynamic web applications.

Leaflet.js: to integrate and visualize the OpenStreetMap map.

D3.js: It is compatible with Angular and offers a wide range of tools for creating custom charts and visualizations.

With this configuration, it will be possible to develop a powerful and dynamic frontend using Angular and the mentioned libraries to create an interactive and visually appealing user experience.

Leaflet.js in combination with OpenStreetMap will help in developing interactive and personalized maps, improving user experience and simplifying the integration of location-based services.

D3.js allows for dynamic data visualization on OpenStreetMap, which can create advanced and interactive visualizations like routes, markers, real-time data visualization, and interactive charts and graphs placed on OpenStreetMap.

The user interface will have a clean, modern and user-friendly design, putting emphasis on usability and accessibility.

A suitable colour palette and clear visual elements will be used to highlight important information.

Intuitive search and filter controls will be provided to facilitate navigation and information retrieval.

Interactive elements, such as pop-ups and dropdown panels, will be included to provide additional details when needed.

6.1.3 Database

Using PostgreSQL, as relational database management system is suggested for storing the gathered information on transportation infrastructure due to its durability and ability to grow in size. Information on the railway network, major roads, inland waterways, freight terminals, and transportation services will be stored in tables that will be created. Connections will be made between various entities as necessary to allow effective searches.

PostgreSQL provides robust support for structured data with its rich set of data types, making it suitable for applications requiring strict data organization, such as transportation infrastructure management.

PostgreSQL seamlessly integrates with modern web development frameworks and languages, providing developers with a powerful ecosystem for building scalable and maintainable full-stack web applications.

6.2 Architecture design and deployment

The ESEP4Freight platform's architecture is modular, enabling easy scalability and maintenance. It consists of interconnected modules for data management, logic, and user interface, promoting integration of new features and interoperability.

Modules work together in a coordinated manner, with the frontend communicating with the backend through a RESTful API for data exchange. The backend processes requests, accesses the database, and communicates internally for specific tasks like data processing or report generation.

The platform's design is modular, allowing for extension and adaptation, with each module fulfilling specific functions for easier code understanding and maintenance. Separation of concerns is emphasized, ensuring a clear division between presentation, logic, and data access for improved debugging and scalability.

Docker will be utilized for deploying and managing the platform, encapsulating each module and its dependencies in portable containers for consistency across development environments. This simplifies infrastructure management and enables efficient resource scaling as needed.

6.2.1 Software architecture diagram

This architecture diagram in Figure 3 illustrates a web application setup integrating various technologies. The frontend comprises OpenStreetMap (OpenRailwayMap), Angular, D3.js, and Leaflet, providing rich, interactive maps and data visualization. These elements interact with a central API, acting as a mediator for backend services. The backend is divided into two main parts: Django, a Python-based framework, and Node.js, each managing different aspects of the application logic and operations. PostgreSQL serves as the database, ensuring robust data management. The entire system is containerized using Docker Compose, facilitating deployment and scalability on an Ubuntu Server, ensuring a stable and secure environment for the application.

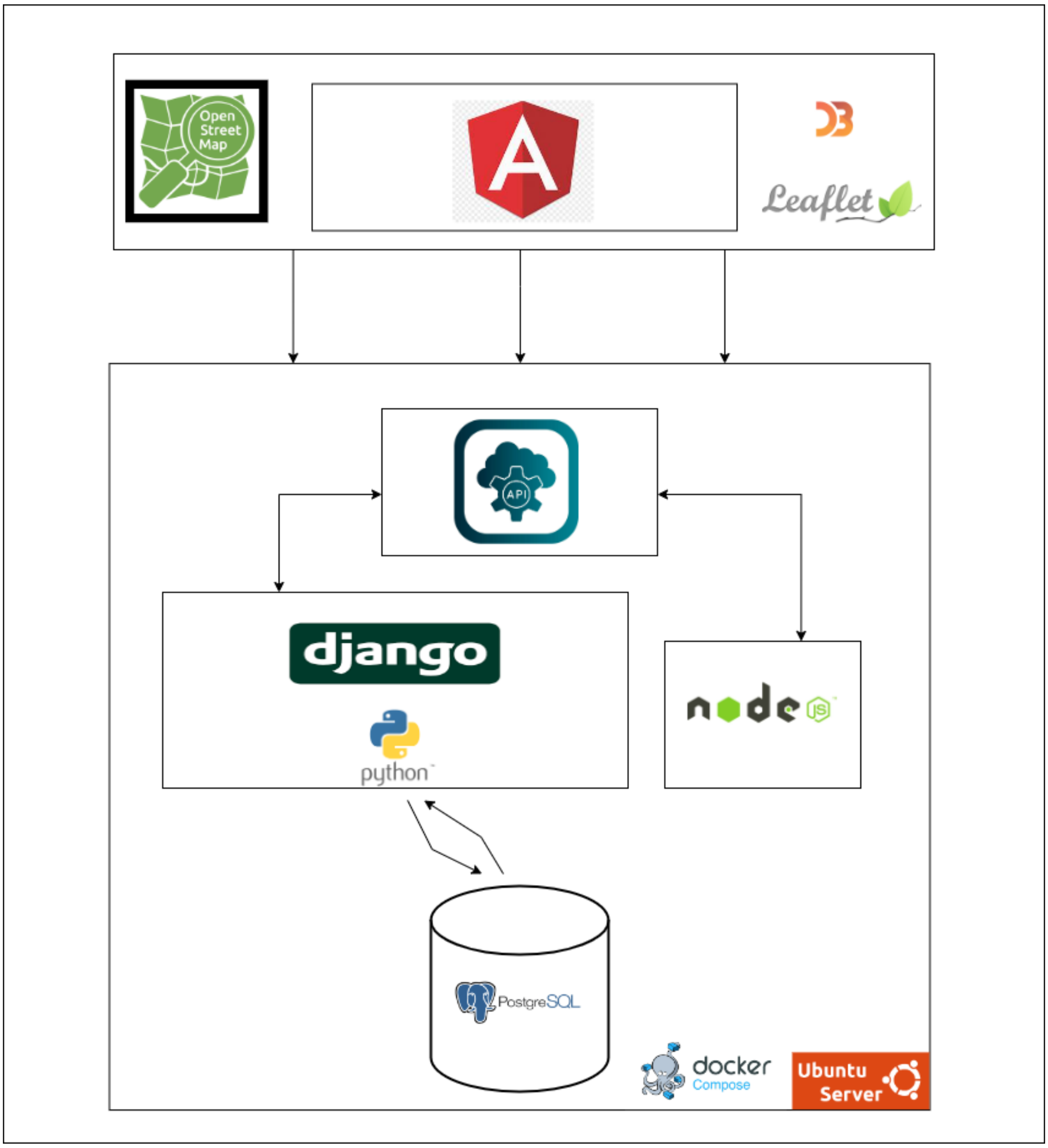

Figure 3 Software architecture diagram, Eurecat, 2024

The stack combines backend technologies like Node.js and Django with frontend technologies such as Angular and Leaflet.js to create a robust and interactive platform.

6.2.2 Class diagram

The class diagram in Figure 4 represents the structure of the system:

At the core we have the *InteractiveMap* class, which interacts with *DataCollection* to manage and display map data and allows filtering of this data. The *User* class provides authentication mechanisms through login and logout functions, enabling users to access the system's functionalities. The *CorridorExplorer* class includes pathways and reports, facilitating the exploration and report generation of freight pathways. The *RouteViewer* class utilizes schedules, transport operators, and the interactive map to view and search routes, and integrate schedules. The *Schedule* class links operators with timings, and the *Operator* class defines these operators. The *MatchMakingTool* class compares terminal services, while the *External Cost Calculator* calculates the external costs of specific route. The *ContractToolbox* class facilitates searching files by name and integrates blockchain technology to execute the proof of concept for applying the e-CMR technology. The *Blockchain* class handles transactions, ensuring their addition and validation. The *Route* class details the origin, destination, mode of transport, and duration of routes, and interacts with the *Location* class, which specifies latitude and longitude coordinates.

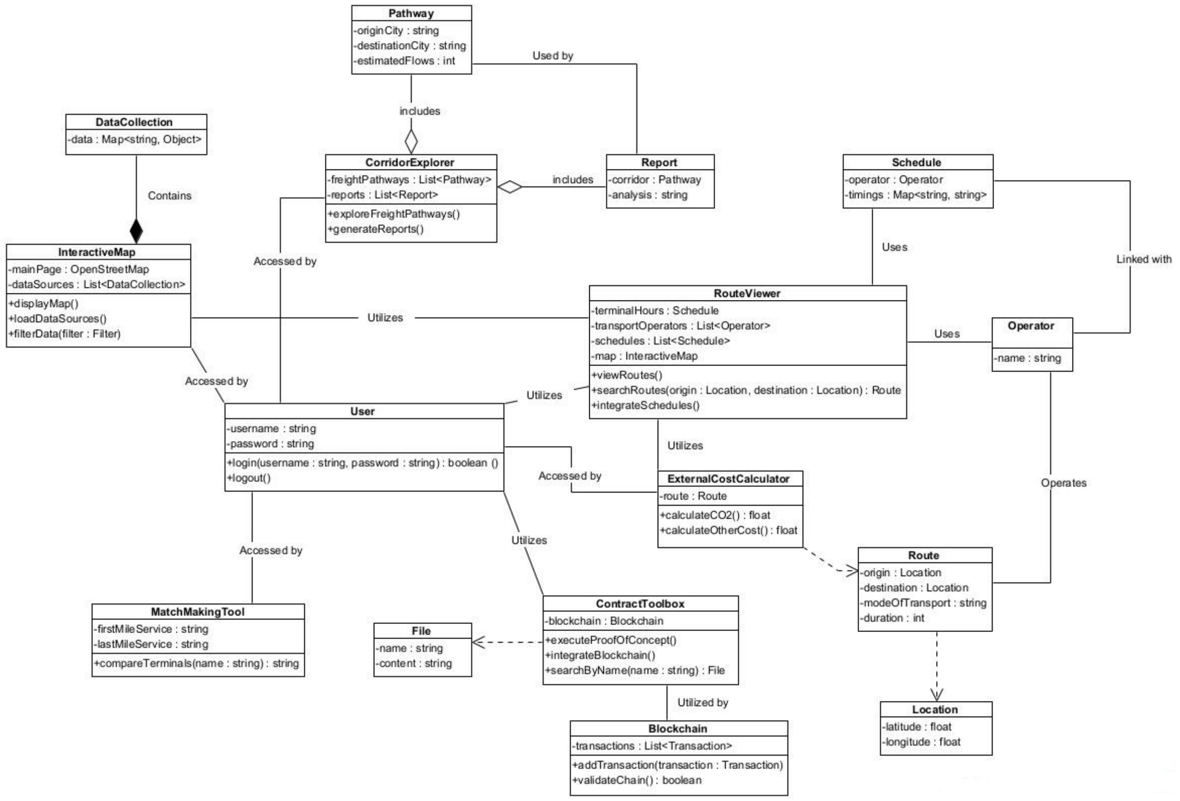

Figure 4 Class diagram. Eurecat, 2024

The class diagram illustrates the system's conceptual structure, including its classes and components.

6.2.3 Use case diagram

The use case diagram for the Platform System in Figure 5 outlines several key functionalities. Users can view routes, which includes displaying maps, and explore corridors, generating reports as part of the process. The system also allows for estimating external cost of a specific route. Other features include executing a blockchain proof of concept, searching and browsing documents, and comparing terminals. Additionally, there is an administrative function for updating and maintaining data.

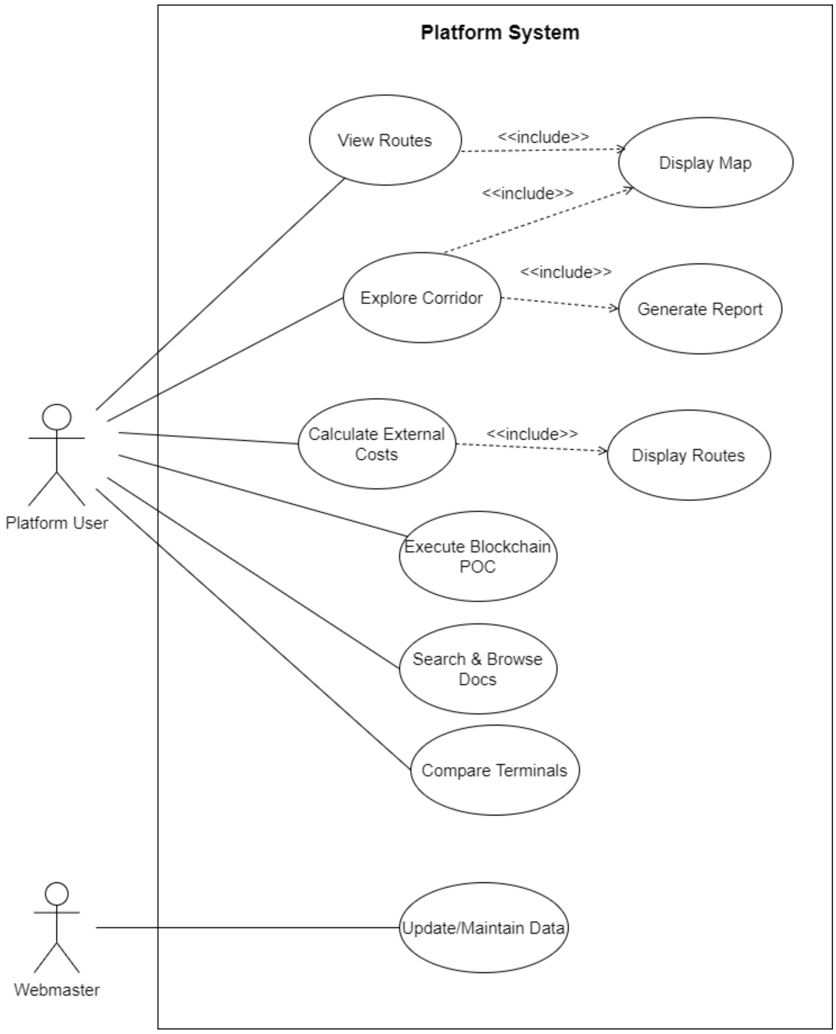

Figure 5 Use case diagram. Eurecat, 2024

This Use Case Diagram provides an overview of the functionalities provided by the platform and the interactions between the user and the system.

6.2.4 Deployment diagram

The deployment diagram in Figure 6 illustrates the architecture of a distributed application using Docker containers and web technologies. Key components include a Node.js module showcasing smart contract functionalities, PostgreSQL with PostGIS for data storage and spatial queries, and a Django application using Python. The user interface leverages HTML5 alongside an Angular application incorporating D3.js for data visualization, Leaflet.js for map visualization, and OpenRailwayMap for railway information. Client-server communication occurs over HTTP on port 80, while containers communicate via a dedicated internal network within Docker.

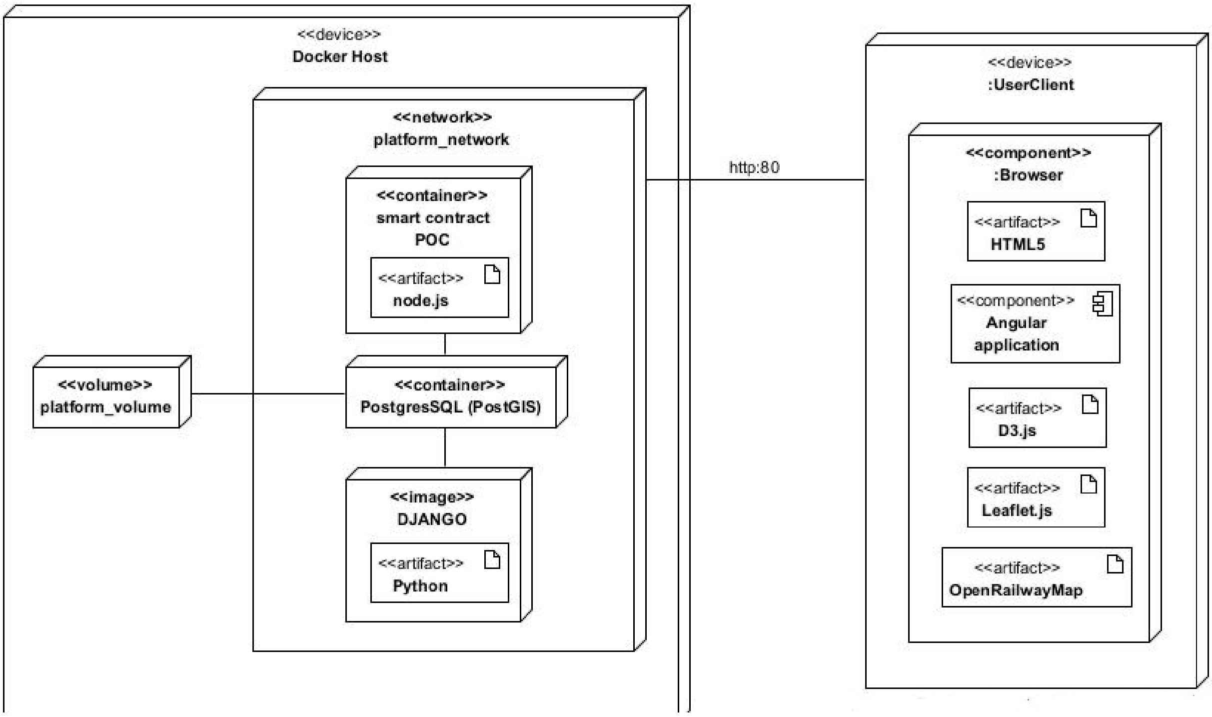

Figure 6 Deployment diagram. Eurecat, 2024

This Deployment Diagram illustrates how the platform is structured for deployment, emphasizing the communication between its elements and the use of Docker for container deployment.

6.2.5 Features of the Web Platform

Interactive map

It is proposed to feature the interactive OpenRailwayMap as the Main Page, displaying detailed information about the transport infrastructure. This map will be integrated with data collected from various sources (Intermodal Map, RNE, Ferrmed, RINF), as well as other public data sources.

Objectives

- Provide users with an interactive experience.
- Integrate detailed data about the railway network, main roads, and inland waterways.
- Allow users to access additional information about freight terminals, transportation services, and connections between different modes of transport.
- Enable users to visualize terminal opening hours, railway operators, and first and last mile connections.

Functionalities

Interactive Map: The main page will show an interactive OpenRailwayMap for users to explore transportation infrastructure.

Data Visualization: Users can view detailed information about railway network, main roads, waterways, and freight terminals directly on the map. All of them grouped in different layers.

Search and Filtering: Users can search and filter information about locations, transportation services, and connections between modes of transport. Also, they can filter by choosing one or more layers in the map.

Freight/intermodal terminals information: Users can access more details about freight terminals, transportation services, and connections through pop-ups or side panels on the map.

Schedule Visualization: Users will be able to visualize terminal and railway operator schedules on the interactive map.

Corridor viewer

It provides users with an interactive tool to explore and analyse freight transport infrastructure.

Objectives

- Enable users to view freight transportation pathways, including the Trans-European Transport Network (TEN-T) and other principal routes.
- Provide detailed information about estimated flows, major origin and destination cities, and high-potential routes (NUTS2).
- Allow users to search for specific information about freight transportation corridors, origin and destination cities, and high-potential routes.
- Facilitate access to detailed reports and analyses on freight transportation corridors and high-potential routes.

Functionalities

Corridor Visualization: Allow users to visualize freight transportation corridors on an interactive map – as different layers.

Information Search: Allow users to search for specific information about corridors.

Access to Reports and Analysis: Facilitate access to detailed reports and analysis on corridors and routes.

Route viewer

It provides users with a tool to efficiently explore and plan intermodal transport routes.

Objectives

- Provide an origin and destination search function to find available routes.
- Develop a route calculator.
- Integrate schedules from different transport operators across Europe to offer multimodal multi-operator solutions.

Functionalities

Route Calculation: A route calculator will be developed that breaks down the transportation network into nodes, considering modes of transport, travel times, cargo restrictions (if available) and external costs (see the 'External costs calculator' feature for details). The schedules may take part on the calculation, if defined.

Origin and Destination Search: Users will be able to search for available routes by entering their origin and destination into the user interface.

Multi-Operator Integration: Schedules from different transport operators across Europe will be integrated to offer multi-operator solutions.

External costs calculator

It offers users a tool to assess and contrast external costs (including CO_2 emissions) related to various transportation options. The results will be part of the results from the route viewer

Objectives

- Develop an external cost calculator based on the SGKV SYSLOG tool and the handbook on the external costs of transport from the European Commission.
- Use industry averages for different modes of transport, considering cargo weight, distances, and modes of transport used.
- Integrate the external costs calculator module with the Route Viewer module to obtain the necessary distances for calculation and show the results in the Route Viewer Module

Functionalities

External costs Calculation: Users may enter cargo jointly with the route information to calculate the external costs for various transportation modes. If no cargo is introduced, standard values will be applied.

Transport Mode Comparison: Users can compare the external costs across different transport modes along a specified route.

Integration with Route Viewer Module: The external costs calculator will be linked with the Route Viewer to access the distance and route characteristics.

Contract toolbox

It provides a centralized location for storing and organizing all state of the art documents generated during the WP2 Project development, apart from the recommendations. It would also allow the users to search for documents efficiently and accurately within the Document Repository.

Objectives

- Establish a storage system to aid in document retrieval and search.
- Enforce security protocols to safeguard the privacy and completeness of archived documents.
- Create a search tool enabling users to search by various regions and document categories.
- Deploy effective search algorithms delivering precise and pertinent outcomes.
- Develop a user-friendly interface allowing users to filter and organize search outcomes as desired.

Functionalities

Search engine: Provide an intuitive user interface for users to navigate and easily find relevant documents.

Blockchain Proof of Concept

A Proof of Concept (POC) for Blockchain solutions will be executed to explore the potential of blockchain technology. It can be seen like a demo, showing a use case and how the smart contract and blockchain technology works and improves the logistic chain

Objectives

- This POC will be carried out to demonstrate the feasibility of utilizing blockchain technology for smart contracts.
- Explore blockchain technology's potential for contract management in freight transportation.

Record the outcomes and discoveries of the proof of concept in a thorough technical report.

Functionalities

This module will be created as a Docker service using Node.js. It will expose an API that allows for multiple functions to be carried out.

Contract example: Users can generate contracts using the API. This includes setting forth definitions, terms, and individuals involved.

Verification of contracts will be made easier through the API, enabling stakeholders to confirm the agreement's validity and authenticity.

Administrators can revoke certificates linked to contracts if needed. This measure guarantees that certificates that are invalid or compromised are no longer viewed as valid.

Contract Updates: The API will facilitate the modification of contracts. Users will have the ability to make changes to terms, addendum, or any other pertinent information while ensuring that a clear history of edits is preserved.

Furthermore, the system will offer contract traceability, enabling stakeholders to monitor the evolution and background of every contract. These characteristic guarantees transparency at every stage of the contract's existence.

Matchmaking directory

Objectives

A repository that aims to collect data on CT actors across Europe, offering a detailed directory with basic contact information. It involves comparing terminals (where data is available) to make evaluations based on factors like capacity, efficiency, and location. This comparison helps users make informed choices about their freight transport plans and logistics practices. Furthermore, the repository provides a selected list of possible first and last mile service provider contacts.

Functionalities

Stakeholder search engine: Users can search for different stakeholder groups and/or regions of Europe to get the initial contact information for key stakeholders as a guide to plan their transports

Terminals comparison: allows users to compare among different terminals. The results will be shown as a form, with the main characteristics of each of the terminals (location, capacity, schedules)

General features

FAQ: Provides clear and concise answers to each question, addressing common user concerns.

Testimonial: Presents testimonials reflecting the positive impact of the project on users.

Contact form: Easy-to-use and intuitive contact form.

Terms and conditions: Clear and understandable terms and conditions for platform users.

Privacy notice: Comprehensive and explicit privacy policy that adheres to data protection laws.

User handbook: Comprehensive manual explaining the platform's features, functionalities, and processes step by step.

6.3 Technical specifications

Below is a description of the main features required for a cloud-based server that will host the Web Platform

6.3.1 Server specifications

Processor: 16 central processing units (CPUs). These CPUs will provide computing power for running applications and processing tasks.

Memory (RAM): 64 gigabytes (GB) of RAM. RAM is used for temporary storage of data that the CPU needs to access quickly. This will allow the server to handle large workloads and process data.

Storage: 240 gigabytes (GB) of storage space. This storage will be used for storing the operating system, application files, and data, databases, logs, backups, etc.

Operating System: Linux-based operating system (e.g., Ubuntu Server) A Linux distribution is recommended for stability, security, and compatibility with the software stack used in the platform.

6.3.2 Server security

Configuration of firewall: To filter incoming and outgoing traffic, a firewall will be set up on the server to only allow authorized connections.

Security measures: such as key-based authentication, disabling root login, and limiting access to specific IP addresses or networks will be implemented to control Secure Shell (SSH) access.

Encryption: SSL encryption protocol will be used to encrypt all sensitive data transmitted between the client and server.

Control of User Access: The server will carefully handle user access, granting each user only the permissions required for their role. Strong password regulations will be implemented.

Comprehensive logging and monitoring: tools will be implemented to trace system behaviour, identify anomalies, and react to incidents. This will involve monitoring unauthorized access attempts, unusual network traffic trends, and system resource usage.

Backup: Data and configurations will be regularly backed up and stored securely offsite for recovery purposes.

6.4 User Stories

6.4.1 Exploring Corridors

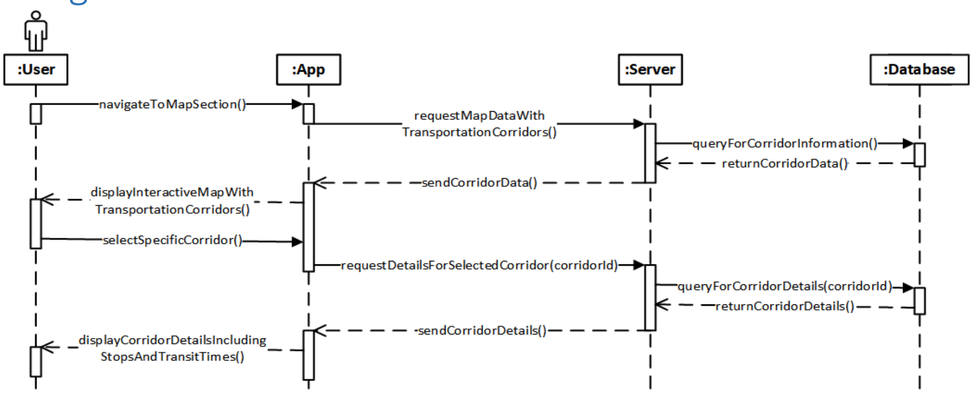

Figure 7 Exploring corridors. Eurecat, 2024

User Story:

As a platform user, I want to explore different transportation corridors so that I can analyse the potential routes for shipping goods

Steps:

User Access: The user accesses into the platform and navigates to the map section.

Map Interaction: The platform displays an interactive map with various transport corridors.

Selection: The user selects a specific corridor to explore further.

- Input data: A corridor

Details Display: Detailed information about the selected corridor is displayed, including potential stops and transit times.

- Output data:
    - Table with the details about the route covered by the corridor, potential stops and transit times.
    - Rail freight flow, for the origin, destination and for the connection, only the ones that are available for the corridor selected
    - Total freight flow, at country level, for the countries covered by the corridor

Validation:

Functional Testing: Verify that users can access and interact with the map, select corridors, and view detailed information.

User Feedback: Collect feedback from users to ensure the routes displayed are accurate and useful.

Backend Verification: Ensure the data displayed corresponds accurately to the database records.

Backend Interaction:

API Requests: The frontend sends requests to the backend to fetch corridor information.

Data Retrieval: The backend queries the Postgres database for corridor details and sends the data back to the frontend.

6.4.2 Viewing Routes

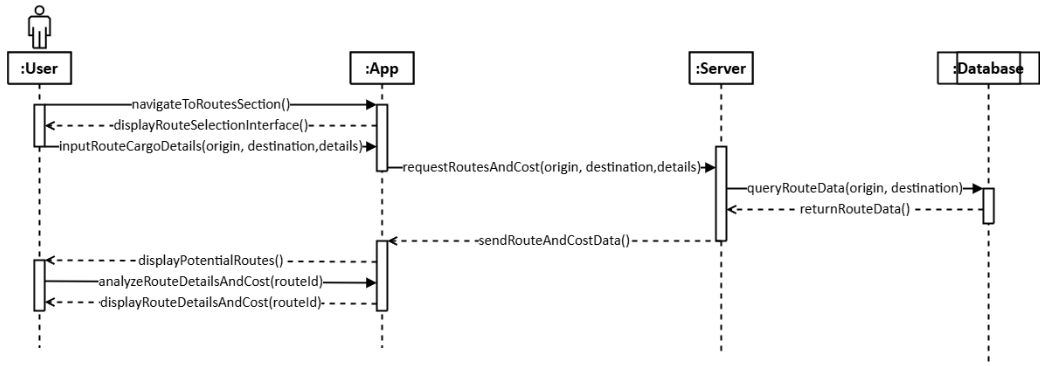

Figure 8 Viewing routes. Eurecat, 2024

User Story:

As a platform user, I want to view and calculate the best routes over corridors and estimate the cost (environmental impact) of different transportation routes. So that I can find the most efficient transportation pathways and most cost-effective option for shipping goods.

Steps:

Access Route Viewer: The user navigates to the "Routes" section.

The user inputs details such as cargo type and weight.

Select Origin and Destination: The user inputs the starting and ending points.

- Input Data:
  - node from the map as origin
  - node from the map as destination

View Routes: The system shows possible routes on an interactive map and in a list and calculates the cost for each one.

- Output Data:
  - List with the origin-intermediate stops-destination. With arrival and departure time at each stop.
  - Route selected from the list depicted in the map. First route by default.
  - The platform calculates displays the environmental impact in terms of CO_2 emissions and other relevant metrics.

Analyse Routes: The user examines route details

- Output Data:
  - List of stops - name – arrival and departure time (if apply).
  - Total travel time.
  - Detail of externalities – including CO_2 emissions.

Validation:

Ensure users can select and view routes and environmental impact.

Validate accuracy of route calculations.

Collect user feedback on route suggestions.

Backend Interaction:

Retrieve route data from the database.

Calculate routes considering various parameters.

Calculates the cost and the environmental impact of different transportation routes.

6.4.3 Generating Reports

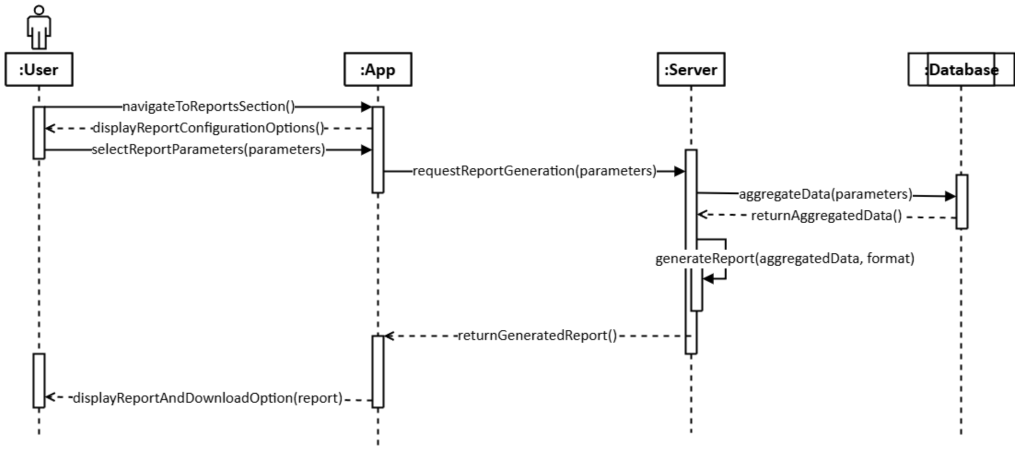

Figure 9 Generating reports. Eurecat, 2024

User Story:

As a platform user, I want to generate detailed reports on transportation options so that I can base my decisions on data.

Steps:

Access to Report Section: The user goes to the "Reports" section on the platform.

Configuration of the report includes the user's selection of parameters like date range, routes, and metrics to be included in the report.

Create Report: The user selects the "Generate Report" button.

Report Processing: The request is processed by the backend, the data is compiled, and the report is generated.

Accessing: The report can be viewed on the platform and downloaded as PDF.

Validation:

Data Accuracy: Make sure the information in the reports is precise and current.

Report Format: Verify the report can be generated and downloaded in the specified format.

User Testing: Conduct user testing to ensure the report generation process is intuitive and meets user needs.

Backend Interaction:

Data Compilation: The backend aggregates data from various sources based on the user-selected parameters.

Report Generation: Utilize library and tool to generate the report in the requested format.

Storage and Access: Provide download link through the frontend.

6.4.4 Executing Blockchain Proof of Concept

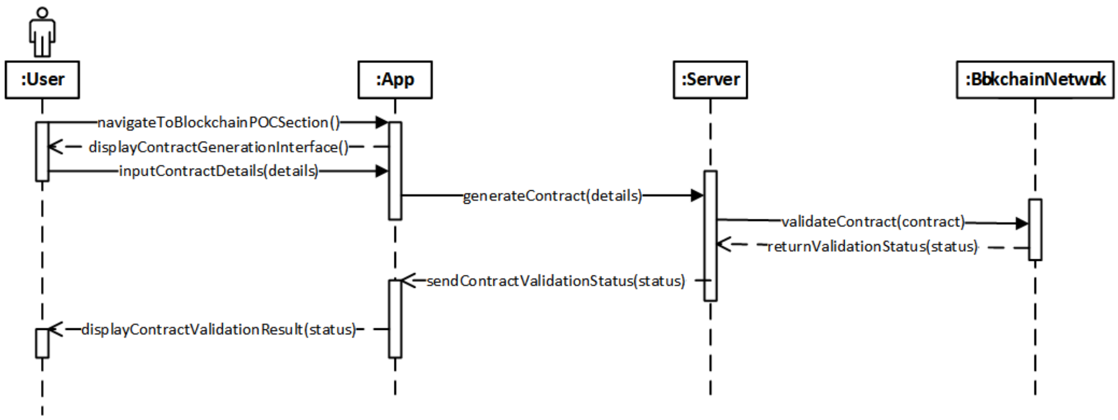

Figure 10 Executing Blockchain POC. Eurecat, 2024

User Story:

As a platform user, I want to execute a Proof of Concept (POC) for blockchain technology so that I can investigate the capabilities of blockchain technology for smart contracts.

Steps:

Access POC Module: The user navigates to the blockchain POC section.

Generate Contract: The user inputs the necessary details to generate a contract.

Verify Contract: The user uses the API to verify the contract’s validity.

Validation:

Functional testing to ensure all blockchain-related functionalities work.

Collect user feedback to refine the process.

Verify backend interactions for data consistency.

Backend Interaction:

API requests to generate and verify contracts.

6.4.5 Searching Documents

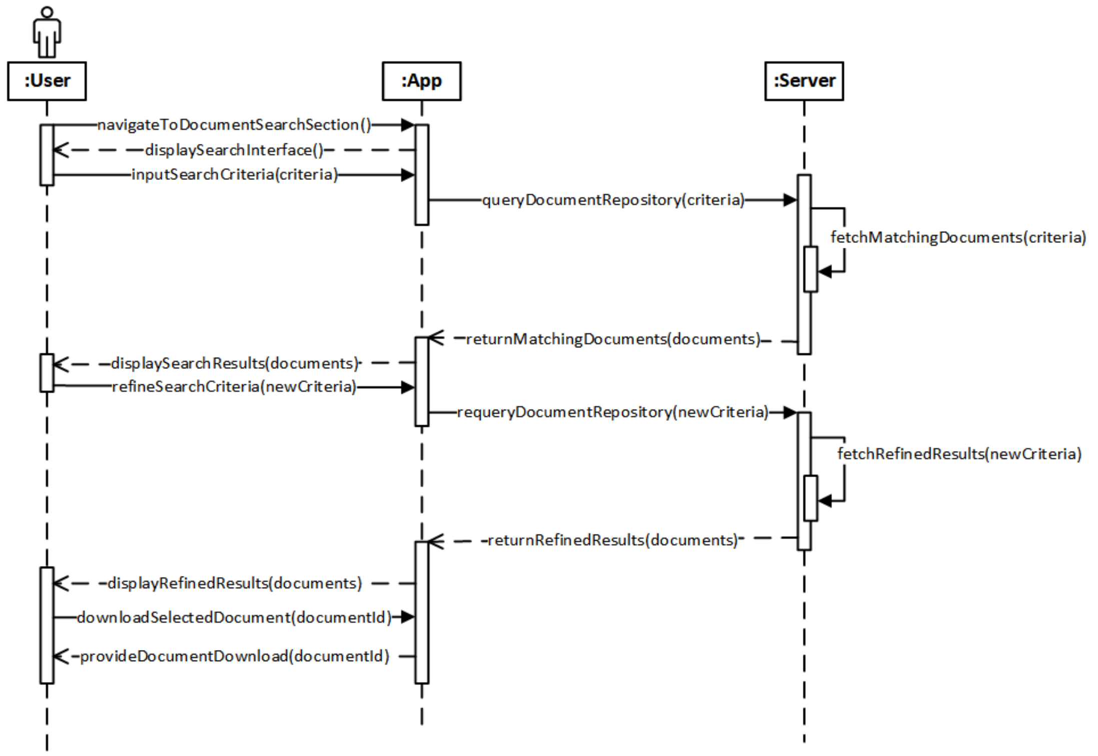

Figure 11 Searching documents. Eurecat, 2024

User Story:

As a platform user, I want to search for specific documents so that I can quickly find and download the information I need.

Steps:

Access Search Tool: The user navigates to the document search section (Contract toolbox).

Input Search Criteria: The user enters keywords, regions, or document categories.

View Results: The system displays relevant documents in an organized manner and display documents details.

Refine Search: The user can filter and sort the search results as needed.

Download results: The user can download results as needed.

Validation:

Ensure search functionality is accurate and fast.

Ensure the interface is user-friendly.

Validate the relevance of search results.

Collect user feedback to improve search algorithms.

Backend Interaction:

Query the document repository for matching entries.

Sort and filter results based on user input.

Return and display results to the user.

Facilitate document downloads securely.

6.4.6 Terminal comparison

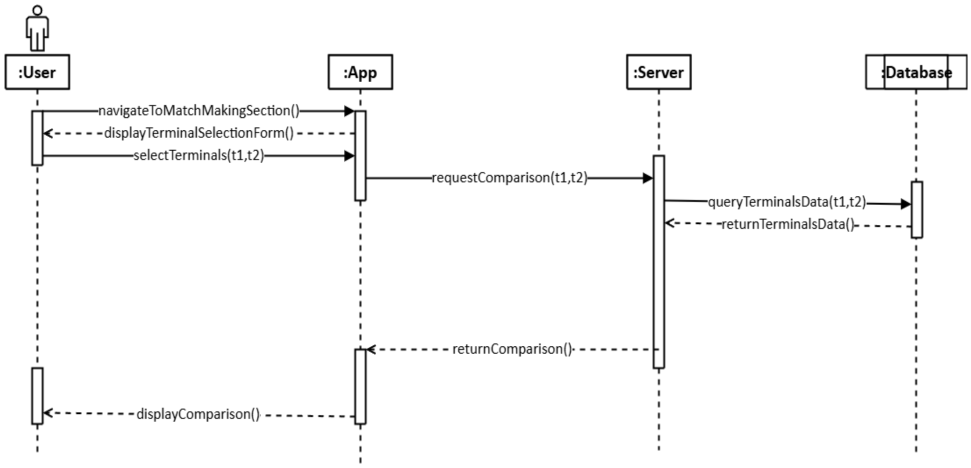

Figure 12 Terminal comparison. Eurecat, 2024

User Story:

As a platform user, I want to compare two terminals based on various criteria like location, connections, terminal services, transport services, and other factors, so that I can make informed decisions about logistics planning.

Steps:

Access Match Making Module: The user navigates to the "Match Making" section of the platform.

Select Terminals: The user selects two train terminals (by name or location) for comparison from a list.

View Comparison: The system displays a side-by-side comparison of the selected terminals, covering aspects such as connections, services, and operational metrics.

Validation:

Ensure that the comparison is accurate and covers all relevant criteria.

Verify the ease of use in selecting and comparing terminals.

Gather user feedback to improve the comparison process and the relevance of additional resources.

Backend Interaction:

Query the database to retrieve details on the selected terminals.

Display the comparison results in a clear and user-friendly format.

7 FAIR Principles, Open data and Interoperability

The architecture of the Web Platform follows the FAIR principles. The architecture has been defined to enable the availability of the metadata on the Web Platform (Findable) and to ensure that the data published on the platform is always obtainable, although the data availability is restricted in some cases (Accessible). Furthermore, collaboration potentials with other research projects in like FP5-TRANS4M-R and ADMIRAL have been studied to ensure a cohesive development of solutions for the rail sector. Likewise, the semantic framework from the DTLF ontology has been followed to ensure interoperability. All the modules of the Web Platform would be accompanied with their respective reports without restrictive licences by the Web Platform manager to allow for transparency and possible reuse. Here it is important to note that the data ownership and right of reuse controlled by certain data providers are not under the purview of the platform developer/manager[22]. A more detailed analysis of the application of FAIR principles to the different datasets used in the Web Platform will be included in the Data Management Plan (DMP) to be submitted at the end of the project.

As one of the main goals of the project is to provide information to the logistics sector to facilitate the shift of goods to rail, the open access of the project results is key to guarantee the success of the project. Following this guideline, the Web Platform architecture has considered the inclusion of a section wherein the various scientific results will be published apart from their publication in open data repositories during different stages of the project. These include for example, the ESEP4Freight guidelines and recommendations, user guide for the Web Platform, and validation results. Moreover, as much as possible, the data sources used to create the Web Platform contents have been sourced from open access materials like OpenStreetMaps[23], RINF database, among others. Apart from these considerations, it is also envisaged to make the datasets and models from ESEP4Freight available for exploitation by the academia, industry, etc. provided they do not include GDPR protected data or commercial sensitive data.

The architecture of the ESEP4Freight Web Platform has been made modular and interoperable by design. For example, the terminology of the platform follows the approaches adopted in RINF[24], Primary and Subsidiary location codes (RNE-UIRR) and the Federated project ontology by DLTF. Besides these, the use of proprietary software tools has been avoided. Furthermore, through collaborations with other projects as mentioned above, the development of an interoperable solution for the single European market was ensured.

[22] https://www.openaire.eu/how-to-make-your-data-fair
[23] https://www.openstreetmap.org/
[24] https://datainterop.era.europa.eu/era-vocabulary/

8 Conclusions

The architecture of the ESEP4Freight Web Platform forms the core of the ESEP4Freight project, since it specifies the technical framework for the development of the platform wherein the project results and data would be published in different interfaces. Based on the state-of-the-art analysis, it was clear that many existing solutions focus only on specific transport modes, and it is therefore challenging for logistic players to visualise the potentials for modal shift to sustainable intermodal transport. Another common problem was that, although actionable data was available, there was a lack of consolidation of data from different sources on an integrated platform. Hence, the aim of this project was to develop a service-oriented platform to support the shift to cleaner transport modes for freight consisting of a central repository and API interfaces to serve the distinct modules and the web-based graphical user interface.

The objective of this specific deliverable was to define the reference architecture of the Web Platform. Based on the state-of-the-art analysis and the stakeholder requirements, the framework of the Web Platform was defined. Furthermore, certain additional data collection actions were initiated to collect the intermodal timetables, benchmark for the newly added external cost calculator, and the stakeholder's contact information. Based on these aspects, the architecture of the Web Platform encompassing the technologies, diagrams for IT design and deployment, features of the Web Platform, technical specifications and user stories was defined. This enables the development and validation of the Web Platform in the following tasks and work packages.

Although no direct integration initiatives with projects like FP5-TRANS4M-R and ADMIRAL has been identified so far after collaborative discussions, it is planned to continue the regular exchange to explore the cooperation possibilities continuously. Adoption of the DTLF Ontology and FAIR principles enabled the creation of an Open data and Interoperable architecture for the platform. Therefore, this deliverable has laid the foundation to develop a Web Platform that would allow the logistic players to visualise the potentials for modal shift to sustainable intermodal transport on a single consolidated platform. This enables the development of tools and functions, and then their integration on the Web Platform in the forthcoming tasks in work package 3. Furthermore, it is also envisaged to update the architecture and the Web Platform itself when required based on the feedback of the stakeholders during the validation process in work package 4 of the project. The modular approach followed for the architecture definition also allows for future extensions and adaptations.

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