MULTIMODAL MOBILITY SCENARIOS TO ASSESS THE PERFORMANCE OF THE EUROPEAN TRANSPORT SYSTEM

Modus

SJU - ER4-10 Modus

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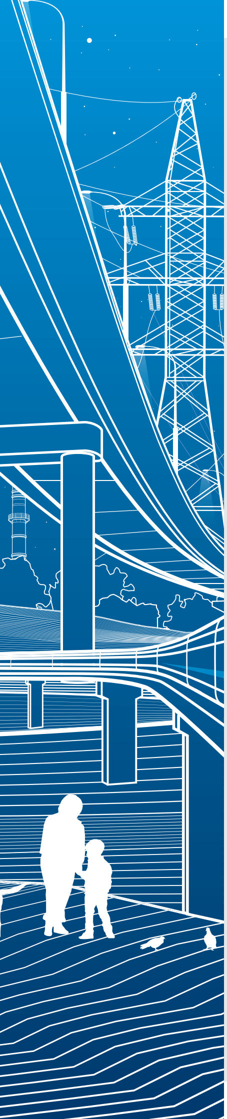
Facts & Figures

1 MILLION EUROS PROJECT BUDGET	**7** PARTNERS	**5** COUNTRIES
89116 GRANT AGREEMENT	**30** MONTHS DURATION	PROJECT COORDINATOR **BAUHAUS LUFTFAHRT** WORK PROGRAMME **H2020-SESAR-2019-2**

Bauhaus Luftfahrt The Aviation Think Tank
ENAC
UNIVERSITY OF WESTMINSTER
innaxis
uic INTERNATIONAL UNION OF RAILWAYS
skymantics
EUROCONTROL



Modus Brochure

"Modelling and assessing the role of air transport in an integrated, intermodal transport system"

The topics of multimodality, passenger experience and inclusion as well as creating a seamless mobility system within Europe that meets the goals of the Paris Climate Agreement, are high on the agenda of shaping the future European transport system.

The Modus project focused on modelling and assessing the role of air transport in an integrated, multimodal transport system, with a focus on joint air-rail mobility.

This approach helped in gaining an enhanced understanding of multimodal traveller requirements, air-rail modal choice decisions and advancing and implementing models to better depict passengers' door-to-door journeys, and to do so across different future mobility scenarios.

As a key result, a modelling approach for the assessment of seamless door-to-door multimodality and the passenger experience in Europe has been developed. It was applied to evaluate the impact of an improved, joint air-rail transport system, characterising the contribution of air traffic management (ATM) and air transport to the improvement of travellers' multimodal journeys. This has been done across four different future scenarios that depict potential development pathways of air-rail mobility in Europe, including a significant short-haul shift from air to rail, traffic growth with strong technological support, or a move towards a more decentralised, remote and digital mobility.

The Modus modelling approach can be used to assess the resulting impacts on capacities, predictability, and the environment, across these scenarios and for multimodal journeys. This can provide useful support for policy makers as well as transport service providers in shaping future multimodal mobility.

Objectives

1

MULTIMODAL DOOR-TO-DOOR MOBILITY

Understanding the potential contribution of ATM and air transport to improve passengers' intermodal journeys and how this translates into an enhanced performance of the overall transport system, including

- identifying and assessing (future) drivers for traveller demand and supply of mobility, and how these affect passenger mode choice, and
- the development of scenarios and passenger archetypes that depict various potential future development paths which the European transport system might be facing.

2

MULTIMODAL PERFORMANCE ASSESSMENT

Applying and further advancing existing models to determine the demand allocation across different transport modes, especially air and rail, and the effects on the overall capacity of these modes, with

- an integrated modelling approach which includes the development of data-driven models of air and ground passenger transport in Europe, together with a passenger modal choice intended to capture the outcomes of different passengers' behaviour, and their effect across multimodal scenarios in Europe, and
- the consideration of passenger mobility metrics that enable quantitative insights into the performance of the European transport network.

3

WAY FORWARD

Developing and assessing performance and connectivity indicators which facilitate the identification of gaps and barriers in meeting high-level European (air) transport goals, and solutions to gaps can be addressed.

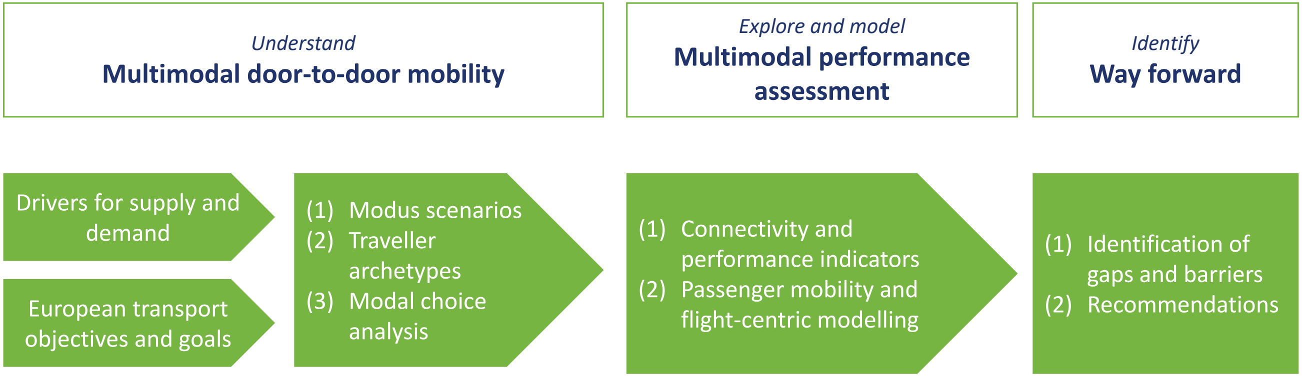


Figure 1: Modus approach

In line with these objectives...

The Modus project was divided into three main technical work packages;

WP3, WP4, WP5

and accompanied by a comprehensive communication and dissemination strategy;

WP6

as well as a detailed data management:

WP2

All related public deliverables are available on the dedicated Modus website:

modus-project.eu

Furthermore, the consultation of an Industry Board and other mobility experts along the entire course of the project provided valuable insight and feedback to the project work.

Multimodal door-to-door mobility

Within the first pillar of the Modus project, the focus has been placed on understanding in a better way how multimodal journeys of travellers can be improved, and which factors affect modal decision making along different future development paths of the European transport system.

First, those drivers were identified and analysed which have an impact on the supply of and demand for future air-rail mobility solutions.

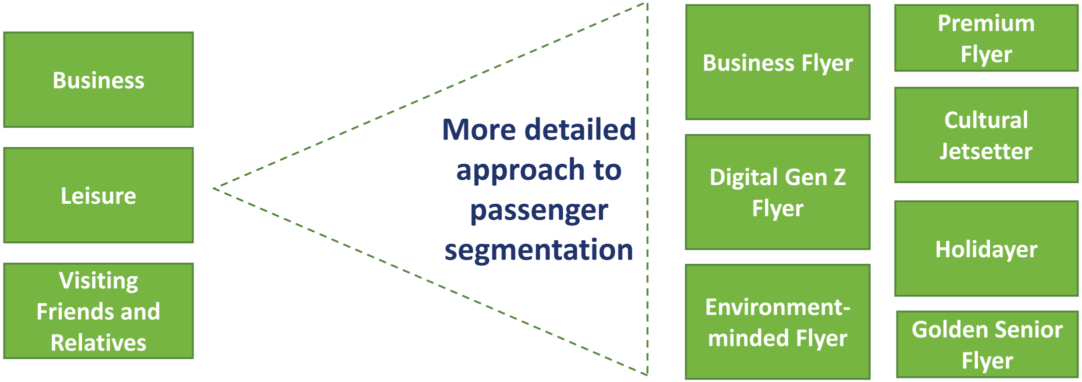
A subset of these factors has been integrated into a modal choice analysis to assess market shares for air and rail in Germany, France and Spain, and to identify price elasticities for these markets (see results in Table 1). A price increase leads to a decrease in demand across all modes, countries and service types analysed in Modus. As the results reveal, this effect is stronger for low cost carriers, and more pronounced in Germany and Spain.

Table 1: Price elasticities of demand per mode, service type and country

	France		Germany		Spain	
	Network carrier	Low cost carrier	Network carrier	Low cost carrier	Network carrier	Low cost carrier
Plane	-6.03 (1.18)	-4.74 (1.9)	-6.11 (7.04)	-13.54 (7)	-17.58 (7.07)	-28.53 (0.56)
Train	-5.21 (1.4)	-3.01 (1.54)	-4.62 (4.13)	-13.45 (7.83)	-1.54 (0.38)	-14.32 (6.24)

In order to understand and assess future multimodal door-to-door journeys, the passenger perspective is of high importance.

Since requirements and resulting travel behaviour can differ, seven distinct traveller archetypes have been developed within the Modus project.



In addition to this, the Modus scenarios (see Figure 2) are the result of the assessment of European high-level mobility objectives, strategic research agendas, existing scenario studies, and the review of investment and deployment strategies in the air and rail sectors.

In line with European high-level mobility objectives, particular emphasis was placed on connectivity, the environmental impact of mobility, the integration of additional demand, and technological innovation and its (widespread) implementation.

Scenario 1: Pre-pandemic recovery
- Network structures remain similar to todays
- Implementation of innovative technologies facilitates the reduction of emissions in air transport

Scenario 2: European short-haul shift
- High share of short-haul air traffic replaced by air-rail cooperation
- High quality of transport network with HSR services on short-haul distances

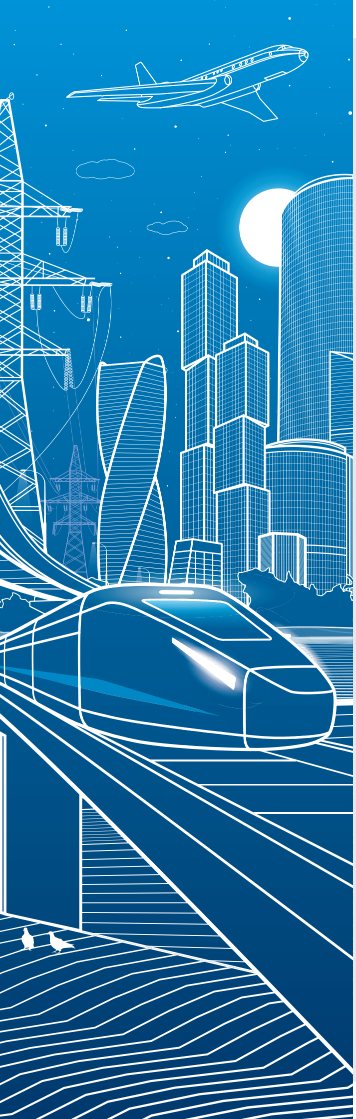
Scenario 3: Growth with strong technological support
- Higher growth rates of the transport sector until 2040 than the baseline
- uptake of technological innovations to both reduce emissions and alleviate capacity shortages in air transport

Scenario 4: Decentralised, remote and digital mobility
- Population becomes more dispersed across rural and remote regions with increased options for remote working and virtual meetings
- More decentralised air transport network, additional railway stations
- Technological innovations for regional aircraft

Figure 2: Modus future supply and demand mobility scenarios

Contributing to improve the passenger experience during door-to-door journeys with a better understanding of customer, market and societal expectations and opportunities, leading to a customer-centric transport system.

The detailed results of these aspects relating to door-to-door mobility are documented in Modus Deliverables D3.1, D3.2 and D5.2 (Final Projects Results Report).



Multimodal performance assessment

Air-rail multimodal mobility has the potential to play a significant role in addressing European mobility challenges such as emissions reduction goals, and capacity shortages, and in moving towards a wider European multimodal transport network.

There is still a need to better understand the potential role of rail when substituting current air links both from a strategic and a full, tactical mobility perspective, particularly when passenger connections are considered.

Modus focused on the development of an innovative approach towards data driven, integrated air-rail modelling, considering passenger door-to-door itineraries. Therefore, passenger mobility has been assessed using two simulation models.

Both models (Mercury, R-NEST) originated as air traffic simulators, and have been extended to take into account the possibility of rail travel and other components of the trips that are needed to calculate door-to-door metrics.

The models now encompass different trip stages, which differ slightly between air and rail parts. The modelling approach is the decomposition of the total travel into different stages. Furthermore, the holistic approach in Modus, integrating air and rail in the wider, door-to-door context, prompted the development of city archetypes, rather than focusing on airports or railway stations per se.

A city archetype denotes a specific combination of airport and railway connections and allowed us to generalise the modelling based on the construction of typical urban travel infrastructure.

Table 2: Modus city archetypes

City archetype	Airport archetype	Railway connection to airport	Further railway info (where applicable)
Arch-1	Main hub	Good inter-regional, direct HSR to airport	-
Arch-2	Main hub	Good inter-regional, no direct HSR to airport	HSR connected to the city only
Arch-3	Secondary hub	Good inter-regional, no direct HSR to airport	HSR connected to the region only and/or good mainline rail
Arch-4	Large/Medium	Good interregional, no direct HSR to airport	
Arch-5	National/regional	Near good inter-regional, no HSR	

In order to assess the multimodal performance across a subset of the previously outlined Modus scenarios, a number of experiments have been designed to evaluate the impact on key (multimodal) performance indicators, including door-to-door (D2D) travel times, average flight waiting times, flight delays, or gate-to-gate CO_2 emissions.

Assuming a shift from air to rail on connections below 500km, and only for city pairs with available high-speed rail links, the analysis in Modus reveals a potential move between 2% and 3% of the expected air demand in 2040.

On the air transport network level, the Modus modelling approach reveals a potential reduction in flight delays, ranging from 10% in the short-haul scenario up to 23% in the highest traffic growth scenario, or a reduction in network D2D travel times by up to 8%.

Table 3: Mercury results - Traffic and passenger flows with D2D averages

Exp. #	Description	Air	Rail	Key metrics				
				Flights	Air pax¶	**Pax S2R** **Cancelled pax**	Network D2D average¶	Short-haul ban states D2D average† ¶
1	Current baseline	2019 traffic	2019 network	**31 080**	**4 029 k** *1 950 k*	-	*467 mins*	*422 mins*
2a	Future baseline	2040 base growth	2040 network	**44 900**	**5 920 k** *2 720 k*	-	*469 mins*	*424 mins*
2b	2a + short-haul ban†			**1360 banned**	*110 k* banned	***110 k*** ***1.6 k‡***	*445 mins*	*402 mins*
3a	Future high growth	2040 high growth		**52 200**	**7 190 k** *3 220 k*	-	*439 mins*	*394 mins*

† Values in this row/col refer to the four countries in which the short-haul ban is applied (Great Circle Distance < 500 km not operated by air in DE/FR/ES/IT, where rail alternatives exist)

¶ Values in italics refer to passengers travelling on the OD pairs within the 176 European airports for which Modus applied city/airport archetypes

‡ Cancelled due to exceptional circumstances, e.g. substitute air-rail-air itineraries being impractical

To support the ATM system analysis a data acquisition plan to collect, store, clean, and pre-process the necessary data for technical activities in work packages 3, 4, and 5 has been developed along the life of the project, adapting to data owners' requirements. Consortium members' internal databases that already contained some data have been a starting point of the data collection task (e.g., traffic data). Also, other public data and commercial databases have been considered, based on the modelling requirements. A key challenge for the project has been the robust parameterisation of the scenario variables in the simulation and other quantitative modelling. The multimodal focus in particular, for air and rail joint mobility, requires coherent datasets for supply and demand modelling. The availability of this type of data is different for the various transport modes and therefore enormous extra effort had to be invested in data acquisition and processing to obtain disaggregated route-level data for the different markets and scenarios considered in the Modus analysis.

The detailed modelling results for passenger door-to-door mobility are outlined in Modus Deliverables D4.1, D4.2 and D5.2 (Final Projects Results Report).

Way forward: Gaps and enablers

The research results have been analysed and discussed with experts from the aviation and railway sectors throughout the entire project, via the Modus Industry Board in the form of surveys, individual interviews and within three workshops including dynamic sessions organised online with more than 300 participants in total. The project results have also been shared and discussed with representatives from academia and relevant stakeholders at several international events. The goal was to gather, discuss and assess various perspectives and insights in regard to what constitutes truly multimodal mobility within Europe, and which areas of improvement need to be addressed and prioritised.

Participants from different transport domains, especially air and rail, provided feedback and discussion on the Modus scenarios and use cases, and highlighted current barriers and enablers as well as opportunities necessary for enhanced multimodality. It was suggested that transport strategy should move towards smart contracts with travellers, and integrated traffic management (TM) independent of the transport mode, and the importance of the link between ATM (air traffic management) and rail TMS (transport management system) was stressed. This enhanced collaboration will enable transparency on services and regulations for passengers. IT/telecom capabilities need to be aligned with transport strategy and the GDPR has to be accommodated with smart contracts, for example.

Furthermore, infrastructure developments will be a major enabler of multimodal solutions, or can impose a significant barrier otherwise. Extending the high-speed rail network in Europe, including the incorporation of airports, and facilitating the interchange and transfer between these modes, especially in terms of luggage handling, and inclusion of all travellers are key elements of enhanced multimodality. Today's processes required in a door-to-door journey are different between air and rail in terms of check-in, security control, passport control or boarding, for example, and also exhibit potential for improvement and alignment.

A very important and decisive enabler is the policy and regulatory framework enabling increased cooperation and seamless travel across transport modes. The rules for consumer protection need to be updated to include multimodal transport, and a comprehensive framework for data sharing and protection has to be established.

The experts suggest that currently issues like differences in airline content distribution (e.g. filling schedules and fares, using e-tickets) and train operations (more location codes, single tickets etc.) hinder a harmonised approach. The question of liability in terms of disruptions, delays or other irregularities has to be specified in order to set incentives for enhanced collaboration between modes.

Table 4: Potential enablers and barriers for future multimodal transport

High-level category	Enablers	Barriers
Infrastructure improvements by 2040	Information/ data sharing IT System D2D / passenger data sharing / Collaborative processing across modes Trust between modes/collaboration Complementarity between air & rail for security Connectivity	Infrastructure capacity Airport design Network integration Security
Business models evolution by 2040	Regulation to ensure level playing field for service providers Intermodal transfer accessibility and efficiency Better passenger disruption services & tools ICT on D2D Passenger flow at airport Provision of a seamless, single booking tool Regulatory framework	Data sharing and management Trust between modes / collaboration
Improvement for passengers 2040	Regulations Booking and ticketing (tools) Information to improve passenger experience Journey planning Personalisation of travel Luggage handling infrastructure Green travel Ticketing innovations Accessibility and comfort	Price and cost Passenger journey experience Information in disruption (Improved stakeholder stress & inclusivity)

Another specific focus was placed on passenger needs and requirements in regard to door-to-door travel. Many elements contribute to a seamless door-to-door journey for travellers. One of these is the ability to book one-stop door-to-door mobility offers by only one contractual partner and via a single platform. Currently, there are undertakings that aim at integrating railway and airline standards into a common platform.

Another important aspect is the provision of real-time information, especially in case of delays and distributions, and according travel management by offering rebookings to passengers. Information also plays an essential role in the personalisation of future journeys, with tailored choices, richer content and better services.

Table 5: Travellers in the centre

What do travellers want?
▶ Seamless travel / D2D offers
▶ Coordinated mobility
▶ Guarantees / protection
▶ Perception of comfort and security
▶ Informed decision-making
▶ End-user-centric systems
▶ Affordability (depending on travel purpose)
▶ Reliability
▶ Sustainability (future driver of travellers)
▶ Accessibility (physical or non-physical / inclusion
Knowledge about travellers' demand is key! Potential change from a supply-push system towards a demand-push system (e.g. in rural areas)

From these various interactions and discussion with experts from the different mobility domains and beyond, the following enablers are considered to contribute in an essential way in further advancing a truly multimodal system in Europe, with a particular focus on air-rail mobility.

Conclusions

The main objective of the Modus project was the focus on modelling and assessing the role of air transport in an integrated, multimodal transport system, with a focus on joint air-rail mobility. In particular, a modelling approach for the assessment of seamless, door-to-door multimodality and the passenger experience in Europe has been developed. It was applied to evaluate the impact of an improved, joint air-rail transport system, characterising the contribution of air traffic management (ATM) and air transport to the improvement of travellers' multimodal journeys.

Re. Objective 1 / Multimodal door-to-door mobility
Understanding the potential contribution of ATM and air transport to improve passengers' multimodal journeys and how this translates into an enhanced performance of the overall transport system

In terms of understanding multimodal door-to-door mobility, a main part of the Modus project has been the identification of future drivers of supply of and demand for multimodal mobility. A wide variety of factors has been assessed showing the complexity and interlinkages across social, political, environmental, technological, and economic decision-making factors. This multitude of influences evokes different travel behaviour as well as infrastructure investment and development. In the Modus project, these potential development paths have been captured in the form of four future multimodal scenarios, including the pre-pandemic recovery (the baseline case), a European short-haul shift, strong growth with technological support, and the move towards a more decentralised mobility within Europe. These scenarios and the qualitative description along a large variety of parameters provide a comprehensive overview as well as the baseline for the derivation of implications for transport providers or policy makers, for example.

A subset of the scenario parameters, such as air and rail traffic growth, or price developments have been quantified in order to be implemented in the passenger modal choice and passenger mobility models. The parametrisation as well as the related data acquisition have been a challenging task, a large number of data sources as well as experts from different transport domains have been consulted for the identification and validation of scenario parameters. The results and overview of the Modus project provide a comprehensive basis for future research and assessment.

The application of the modal choice analysis across a subset of these scenarios as well as to different routes within Europe shows that there is no general statement to be made regarding an air-rail joint mobility strategy. From the analysis, it can be seen that there are routes with already a well-established HSR connection and a high share of rail traffic. The potential of extending rail capacities in the future may therefore have a strong impact on air-rail market shares, and which sector may take up higher portions of additional demand in the future. These considerations have to be taken into account when making investment in infrastructure and/or designing mobility products and services.

Applying the Modus modal choice analysis to different countries and city connections in Europe shows that the own-price elasticity of demand differs in regard to Spain, France and Germany.

In addition to this, seven future traveller archetypes were developed showing the diverse mobility needs and requirements among travellers. A true multimodal transport system is called up to offer mobility services that are tailored towards such personal needs, including differences in trip purpose, value of time or the level of environmental awareness, for example.

Hence, traveller archetypes vary according to their willingness to pay for travel products and services along their journey, or the requirements or process times along each step of the door-to-door journey. These elements are also reflected in the multimodal performance assessment.

Re. Objective 2 / Multimodal performance assessment
Applying and further advancing existing models to determine the demand allocation across different transport modes, especially air and rail, and the effects on the overall capacity of these modes

The multimodal performance assessment in the Modus project built on and extended two well-established simulation models, the Mercury passenger mobility model and the R-NEST tool.

Within the course of the project, both models have been advanced to take into account rail travel as well as door-to-door journeys in order to calculate according metrics.

Furthermore, the holistic approach in Modus, integrating air and rail in the wider, door-to-door context, prompted the development of city archetypes, rather than focusing on airports or railway stations per se.

A city archetype denotes a specific combination of airport and railway connections and allowed us to generalise the modelling based on the construction of typical urban travel infrastructure. This impacts the modelling at two levels.

Firstly, it allows, holistically, the consideration of movements between ‘Paris’ and ‘London’ and the future of such flows, rather than being tied to specific constraints at particular airports, for example.

Secondly, it allows the construction of urban mobility models relating, for example, to airport and railway station access and egress, with generic travel time distributions per archetype. Furthermore, various stages of the air passenger journey from door to door have been defined, both for rail and air passengers.

In order to assess the multimodal performance across the different scenarios, a number of experiments have been designed to evaluate the impact on key (multimodal) performance indicators, including door-to-door travel times (KPA Capacity), average flight waiting times (KPA Predictability), flight delays, or the gate-to-gate CO_2 emissions (KPA Environment).

Each of the experiments has been run with and without a disruption, thus showing the impact on the different mobility metrics. Due to the scope of the project and available resources, detailed experiments have been designed and simulated for the first three scenarios previously outlined.

Re. Objective 3 / Way forward

Developing and assessing performance and connectivity indicators which facilitate the identification of gaps and barriers in meeting high-level European (air) transport goals

The results of the Modus project have shown that there are some essential requirements and key enablers to foster multimodality in Europe.

Among all these recommendations, we believe that it is essential to consider different scenarios, use cases and developments in long-term planning, also given uncertain economic, social and even pandemic-related developments in Europe. Scenarios, such as those presented in this document, can help to make sense of the future and to structure decision- and policy making.

Requirements for a multimodal system

- Close cooperation between air and rail mobility providers to ensure a seamless door-to-door journey for travellers (including data availability and sharing, integration of privacy requirements).
- Holistic approach to meet the climate goals and comprehensive assessment of different modes.
- Integration of remote regions, their connectivity and accessibility, and taking into account diverse traveller needs.
- Emergence of new actors in the mobility market (also outside the transport sector) as well as business models.
- Setup of a regulatory framework for better cooperation.
- Adaption towards local requirements and market needs, e.g. taking into account different network structures.
- A fruitful collaboration between industry and research / science / academia to use the skills and inputs from both worlds.
- A shift towards true multimodality is a change process and needs a mind-set shift at the stakeholders side, too (e.g., align vocabulary).

Enablers of a multimodal system

- Legislation and a regulatory framework to foster cooperation across modes and across national borders.
- Design of measures, policies and incentives which are tailored to specific regions and routes.
- Transparency of all and external costs of transport modes (informed decision making for policy makers and travellers).

- Smart travel: data availability and sharing, the avoidance of disruptions, and/or the dynamic rescheduling of journeys.
- Data and platformatisation (e.g., investments in innovative ideas) to develop a true D2D travel application for travellers.
- Infrastructure investments for enhanced integration of different modes along the travel chain

Along these three high-level objectives, Modus thus achieved to provide a better and more detailed understanding of travellers' requirements along the door-to-door journey, translating the multitude of influencing factors into comprehensive future multimodal scenarios. This is also reflected in the depiction and assessment of connections and dependence between air and rail in particular, as simulated in detail in the multimodal performance assessment for door-to-door journeys.

Dissemination

The project partners attended several conferences and published a series of papers to present the results achieved during project life.

For further information follow Modus in its social networks:

modus-project.eu

twitter.com/modus_project

linkedin.com/company/moduseuproject/

List of project deliverables

Project deliverables, newsletters and other multimedia materials are available at Modus website.

Figure 3: Modus deliverables

Deliverable number	Deliverable name	Work Package	Lead Partner
3.1	Modal choice analysis and expert assessment	3	ENAC
4.1	Interface to modal choice model: methodology	4	INX
3.2	Demand and supply scenarios and performance indicators	3	BHL
5.1	Definition of use cases	5	BHL
4.2	Mobility models description	4	UoW
2.2	Database Structure	2	INX
5.2	Final project results report	5	BHL
6.2	Final Dissemination Report	6	BHL

Public deliverables can be downloaded on the project website at:

modus-project.eu

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