RESEARCH TOPICS – SPOKE 10

1. CONTEXT DESCRIPTION

Logistics and freight transport involve more than 70.000 companies in Italy, for a turnover of about 80 B€. Business growth is constant, despite the pandemic crisis. Unprecedented opportunities for a technological revolution and a full digitalisation of logistics and freight transport are available, enabling new services and business paradigms, including Industry/Logistics 4.0. At the same time, the sector is under pressure due to energy tensions, global disruption phenomena, growing fragmentation of shipments and increasingly challenging level-of-service requirements related primarily to e-commerce, conflicting phenomena of globalization vs. reshoring, volatility/dynamicity of freight flows, unsustainable labour conditions, scarce attention to externalities and collective diseconomies in the optimisation of single distribution chains.

While offering new opportunities, digitalization also brings new risks related to cybersecurity, yielding business interruptions and safety/privacy infringements. The diffusion of Internet-of-Things exacerbates the problem, as devices typically are not cybersecurity-oriented and often deployed in unattended, possibly hostile, environments. Innovative data collection and analytics and business sharing platform open still unsolved legal issues and need for new regulations. Supply chains should be efficient and fast: synchronization of nodes along a logistics network can bring rapidity and reactivity, and freight transport plays a crucial role. Freight transport is a significant component of the total logistics cost and, at the same time, a source of value and competitive advantage. Managing transport systems is a complex task that involves many stakeholders, different ownership of assets, coordination among key agents (shippers, freight operators, receivers), flexibility to react to increasing uncertainty and capacity reduction.

Transport in Europe causes about 25% of CO2 emissions, 36% of which due to freight. Challenging objectives to reduce such carbon footprint have been set at EU level, imposing a radical change of logistics and transport operations. Sustainability – in its threefold declination: environmental, societal, economic – is a necessary target. This is particularly relevant in cities, wherein increase of consumers' purchasing habits and new distribution problems – e.g., a multitude of small parcels to be delivered to dispersed destinations with strict delivery times – can yield negative effects (inefficient performance, increase in traffic and emissions, scarce urban liveability) if faced with traditional logistic solutions. Achievement of sustainability targets is difficult also because logistics and transport are still strongly perceived as a commodity, with a pressure on procurement costs that prevents investments and limits the development of a logistics culture. In this context, the opportunities of the circular economy and of the synchro-modality are not yet fully exploited, as well as the potential of nudging policies to business establishments and final customers. The high level of outsourcing and different types of logistics providers involved is a further element of inherent complexity: oligopolies in many logistics and freight transport sector raise significant and novel planning and operational issues, and complicates policymaking and governance, also in the light of the Italian national Recovery Plan.

In any case, unprecedented data availability and sensing capabilities on logistics and transport networks enable complex real-time optimisation, with evident potential economies of scale, cost savings and better environmental performance. This is straightforward from the perspective of a single company, whilst a system-wide optimisation involving multiple providers in matching demand and operations is not an easy task and represents a relevant research challenge. The Logistics 4.0 paradigm and its related solutions to collect and analyse data foster the implementation of data-driven approaches for decision-making, integrating different players and dealing with uncertainty. New technologies can be the enable factor of the transition towards a greater digitalization and synchronization of logistics processes. Finally, from a public perspective, current system-wide monitoring and knowledge of logistics and freight transport is very limited, preventing effective infrastructural development, assessment of policymaking, design of optimised incentives. Developing innovative decision support systems for planning, management, analysis and incentivisation of freight and logistics systems is another a challenging and timely topic.

2. RESEARCH PROJECT DESCRIPTION

<u>GOALS</u>

- **Pursuing a holistic development of future logistics and freight transport systems** leveraging four main pillars: (1) technological development, digitalisation, and data analytics capabilities; (2) environmental,

societal, and economic sustainability; (3) optimisation of operations and new business models; (4) coordinated and effective policymaking and governance.

- **Developing a technology road map**: adopting advanced methodologies and modelling tools for the analysis and forecast of the impacts of new technologies and business models for logistics systems and freight transportation; developing and promoting advanced technologies and an industrial digital transition, enabling the innovation of organizational systems and operational approaches.
- **Developing a roadmap to increase the sustainability of the sector:** transportation mode rebalancing, supporting the synchro-modality and rebalancing unsustainable road transport by means of integration platforms, organisational solutions, and new technologies; reducing carbon footprint of transport along the entire supply chain.
- **Supporting policymaking:** designing guidelines for legislative changes and infrastructural planning, to enable positive impacts of new technologies and business models on sustainability. Improving the quality and the supply services of the overall national logistic system, to enhance the competitivity of economic companies and business enterprises.
- **Reinforcing the labour market** in logistic and freight transport, to promote professional updating, innovation, and knowledge transfer, to improve work safety first and business competitivity.

METHOD

Activities and related methods of the Spoke are articulated along several research lines, characterising also the project structure illustrated in Section 3 of the proposal. Three research tasks are crosscutting:

Data acquisition/data analytics, cybersecurity, managerial aspects. Digitalization of the logistics processes requires generating, collecting, analysing, and sharing data amongst all agents/devices along logistic chains. Artificial intelligence and Explainable Artificial Intelligence techniques – with a specific focus on machine learning – will be employed to inform and improve efficiency and optimization of logistics and freight transport. Attention will be focussed also on data acquisition and data analytics for real-time responsiveness, resilience, and adaptability of logistic systems. Swarm intelligence techniques will be implemented to develop self-organisation schemes targeting autonomous vehicles, for fully autonomous and decentralized transport management strategies. Solutions to protect security and privacy of logistics process and related data, both in transit and at rest, will be developed. Blockchain's properties, including anonymity, decentralization, immutability and tamper-proofness, will be exploited to support and improve logistics activities such as process certification, management of shipping documents, materials tracking, and fleet monitoring. Managerial aspects will be tackled with the twofold objective of (a) verifying the economic sustainability of freight transport based on environmental-friendly vehicles and (b) proposing actions to reduce costs and improve performance for non-economically sustainable strategies. Strategic planning and management tools – including life cycle assessment, SWOT analysis and cost-benefit analysis will support the appraisal of project activities and outcomes.

Cybersecurity, data protection, legal and regulatory aspects. Relevant legal and regulatory aspects will be tackled from different viewpoints. Issues deriving from data sharing/management and from economic and operational issues in sharing platforms will be addressed by means of a redesign of the related disciplinary framework, combining hard law and soft law interventions. Legal implications of digital divide, autonomous driving, responsibility for failures of smart solutions/algorithms, guarantees for users of sharing platforms will be addressed as well. In the light of Corporate Social Responsibility principles increasingly promoted by Italian and EU regulations and tools, proper governance solutions will be envisaged to grant annual and interim information flows towards the market and within-company on sustainability performances. Economic regulation (e.g., incentives) to promote the achievement of long-term goals will be also investigated.

Sustainability assessment. Economic, social, environmental sustainability are key driving factors throughout all research activities of the Spoke. General aspects related to principles and tools for sustainability assessment will be tackled. A specific research task will be devoted to innovative approaches to assess sustainability enabled by real-time data collection and analytics, and by new solutions like biofuel generator. Consistent innovative methods and policies to foster sustainability will be also discussed, e.g., by means of nudging to customers and business establishments. Technological aspects may vary significantly across applications and will be tackled specifically in each vertical research task, as described below.

Other research tasks are more vertically targeted to tackle relevant specific research questions:

Last mile and city logistics. This task targets innovative last mile and city logistics solutions, integrating new technologies and different transport solutions, compliant with environment, quality of life, traffic congestion, public health, accessibility/inclusivity, safety, and public space. The concept of city-logistics-as-a-service

(CLaaS) will be developed, in terms of a holistic platform that matches supply and demand with an innovative approach leveraging real-time optimisation, prediction of the behaviour of CLaaS platform users', dynamic pricing of services, personalised level-of-service options, and flexibility of usage of assets (vehicles and/or depots/transit points). In parallel, a toolset of smart approaches to support public and private city logistic agents in urban areas will be implemented, to simulate different freight distribution solutions in a multi-objective perspective, adopting a rolling horizon for long-medium term strategic objectives, while considering short-time tactical and operational constraints. Innovative transport solutions will be investigated, based on new management strategies of last mile freight distribution using small and green vehicles, preferably electric, fully automated, but with the possibility of a conventional driving, travelling alone or gathered in platoons. Related optimisation issues will be addressed, both strategical/tactical (e.g., location of charging stations and consolidation centres/transit points) and operational (e.g., eco-routing/eco-driving, smart charging of electric vehicles, dispatching of autonomous vehicles).

FaaS (freight-as-a-service). Transport systems engineering and machine learning will be combined to pursue a monomodal and multimodal integration of freight transport systems, including consolidation of shipments across carriers, to achieve synchro-modality. Trajectory data from GNSS and territorial information (e.g., points of interest) will inform data analytics and data mining finalised to observe/predict freight demand patterns. Discrete choice modelling techniques will be also applied to predict decision-makers' behaviour and to help proposing personalised services with variable level-of-service and pricing. Solutions based on the physical internet framework will be analysed and optimized to exploit the capacity of the already available transport infrastructures and modes at the best. Resilience will be a crucial objective, in a system characterised by frequent disruptions/issues and inherent variability of travel times and waiting times at nodes. The resulting Service Network Design (SND) problems will be faced with stochastic and robust optimization methods, considering explicitly the inherent uncertainty in transport times and handling times at nodes/terminals, as well as energy consumptions and charging times for electric vehicles.

Innovations in logistic/multimodal nodes. The research task will develop an operational model and a system optimisation tool to improve the performance of logistics nodes and reduce their carbon footprint, embedding jointly node-based performance (e.g., queues, throughput time) and network-based performance (e.g., reliable real-time travel time predictions on the relevant road network). Users of the systems (customers of the nodes) will access to descriptive and/or prescriptive information and will be able to optimise in turn their operations. The possibility of using buffer areas in the surroundings of the logistics nodes to split queues and reduce consistently lost times and external impacts will be also explored. Specific attention will be devoted to ports and maritime terminals, with the development of innovative tools/methods to improve their performance and sustainability, pursuing seamless integration between ship, berths, yards, and gates. A specific task will be dedicated to address the routing of electric vehicles in large warehouses characterized by a high index of product rotation, considering, in addition to traditional assignment, scheduling and routing decisions, also recharging operations for the battery during the movement of the vehicles within the warehouse, with a particular attention to the application of vehicle-to-grid and vehicle-to-building technologies.

Innovations in supply chains and in connections between multimodal nodes. This task complements the previous, investigating the change of logistics processes – from off-line/static to dynamic/real-time data-driven approaches – and to improve integration throughout nodes of logistics networks. The ultimate objective is to facilitate sustainable development through better processes, systems, and technologies, whether organizing logistics networks and supply chains in more efficient and environmentally sustainable ways, developing new planning methods, or improving the flow of information throughout the supply chain. Smart logistics and freight transport solutions will be explored, to improve transport reliability. System dynamics approach will be applied to simulate (sustainable) logistic networks and re-configuring procurement, production, and distribution channels relationships. Synchronization of transport resources (e.g., redesign of transport planning) and synchronization between transport activities and logistics nodes (e.g., yard management) will be key topics to address. Models, mainly based on digital twin approach, will be developed to simulate planning and operations within and between the supply chain nodes to improve sustainability, pursued also by increasing the share of greener transport modes, especially rail. Integrated logistics processes will be analysed and redefined, with a specific focus on data-driven management systems for sea-land logistics activities, involving different agents and logistics infrastructures/nodes (e.g., ports, dryports), leveraging the innovations offered by ITS and Industry 4.0 paradigm.

Decision support systems for policymaking and governance. The research task aims to develop an innovative decision support system to simulate the overall multimodal freight transport system in Italy, with monitoring and forecasting capabilities, able to inform more effective and sustainable policymaking. Data

collection capabilities developed in other research tasks of the Spoke will be effectively applied to gather relevant inputs. The decision support systems will be targeted primarily to (a) monitoring and reporting and (b) to serve as a basis to predict freight flows and system performance both in the short term and in the long term. Consolidated transport engineering methods/models will be upgraded, new models/approaches enabled by unprecedented data availability will be developed, and relevant mathematical issues in traffic modelling addressed. The interests of different types of users will be embedded, ranging from public bodies to private operators, and prototypical applications of the tool will allow designing guidelines for infrastructural planning. The tool will also serve to design innovative schemes of incentivisation of sustainable freight transport, to reduce additional costs of non-economically sustainable transport policies.

A final research task is dedicated to dissemination and knowledge transfer:

Dissemination and living lab, innovation training and knowledge transfer. Research activities will be demonstrated in prototypical applications, leveraging availability of data and test beds already developed by the Spoke participants. Companies formally involved in the proposal will contribute actively to testing and deployment. An important part of this research task is the active engagement of various types of stakeholders (e.g., Port System Authorities, public agencies with competence in logistics and freight transport, operators, logistics/multimodal node managers), often with consolidated collaborations already established with Spoke participants. Their practical engagement will be implemented during the project. Key attention will be paid to professional updating and knowledge transfer, also based on active learning methods (e.g., learning-by-doing). High-quality simulators based on human factors will be promoted to support relevant training activities. Living lab will be structured together with companies and stakeholders involved in the Spoke and will be structured in dual layout: virtual (i.e., based on ICT platforms) and on-site. Guidelines for stakeholders and policymakers will be also prepared as a project legacy.

OUTCOMES

- Develop models for supply chains, logistics nodes and freight transport networks, also based on digital-twining approaches, to simulate and optimize planning and operations.
- Develop models and technologies to promote more sustainable modal choices and multimodal/intermodal freight transport, to also achieve synchro-modality, system resilience, and sustainability.
- Develop a mapping and impact assessment of new technologies related to Logistics 4.0 (e.g., cyber-physical systems, physical internet, Internet-of-Things, blockchain, automation and connection between vehicles and/or infrastructures and terminals, cybersecurity, and big data) on the productivity and sustainability of freight transport and logistics.
- Develop new business models based on the economy of platforms (e.g., hybrid multi-sided platforms), distributed systems (e.g., blockchain and web 3.0), and logistics-as-as service; addressing relevant legal and regulatory issues.
- Develop technologies and operational/business models for sustainable and effective last-mile logistics, within the broader concept of urban mobility.
- Develop impact models and system optimization tools for analysing and minimising the environmental footprint of freight transport and logistics nodes and networks.
- Develop new solutions/approaches to exploit the use of real-time information and big data analytics to improve logistics systems, and for public monitoring and policymaking.
- Develop new training protocols for logistic workers based on human factors approach.
- Develop tools for the optimal design and operation of smart charging infrastructures for freight electric vehicles with a specific focus on port applications.

COLLABORATIONS WITH ENTERPRISES

Some of the enterprises participating to the proposal of the National Centre for Sustainable Mobility are directly involved in business activities close to the research proposal of the Spoke. Specifically, Telespazio (a Leonardo/Thales company) will be involved in the research task on last mile and city logistics, with contributions on ITS for commercial fleets and on drone-based pickup/delivery operations, and in the research task on data acquisition and data analytics, thanks to its expertise in high-precision geolocalization. Leonardo Logistics and Almaviva will also collaborate, because of overlapping of their key business areas with the research themes of the Spoke. Crucially, the Spoke is cross-sectional to many enterprises involved in the National Centre, and their involvement will be managed explicitly at the beginning of the project.

DESCRIPTION OF SPOKE PARTICIPANTS

Università degli studi di Napoli Federico II (UNINA). UNINA has a strong competence in logistics and freight transport, with leading expertise in many crucial sectors for the Spoke: transport engineering, logistics and supply chain management, operations research, economics, law, environmental engineering, statistics and data analysis, mathematics. A track record of projects, funding, and international collaboration has been established in each of these domains, as well as a consolidated network of interactions with relevant local and national stakeholders and enterprises.

Politecnico di Milano (POLIMI). The research team has an established know-how in the design and management of logistics and transport systems with three main perspectives. The first is a focus on logistics process optimization (e.g., strategic and operational planning, performance measurement, organization). The second is a deep knowledge of quantitative methods applied to logistics from activity-based costing modelling to location models, predictive modelling, IoT-driven data analytics, dynamic simulation. The third perspective is the strength of our corporate connections, funded research, and technology transfer projects with a couple of notable examples being the Contract Logistics industry and E-commerce (with dedicated Observatories).

Università di Napoli "Parthenope" (UNIPARTH). The activities of UNIPARTH's research group for Spoke 10 are related to the development of innovative practices and tools in managing sea-land logistics processes. The expertise of the research team - focused on logistics & transport, port & maritime logistics sectors - will provide a relevant contribution to the project activities in order to make supply chains more efficient, sustainable and faster with a particular focus on sea-land logistic node connections and implementation of environmental monitoring systems. In particular, the researchers will contribute to the project proposal thanks to the considerable experience acquired over the years in developing innovative decision support systems for the analysis, planning, management, and promotion of freight transport and logistics systems. UNIPARTH's research group will also focus on dissemination and training activities (i.e., learning by doing).

Università di Genova (UNIGE). UNIGE is a public institution founded in 1933 provided with scientific, educational, organizational, and financial autonomy and it participates in the building of a European Area for Research and advanced professional training. UNIGE has a strong participation in the most important EU and international research and cooperation Programs, in particular it is currently involved in many projects funded under S2R, HorizonEurope, H2020, CEF, FESR-Interreg, LIFE, and other international funding instruments. Its main sites are located in Genoa and Savona. In particular, the labs involved in this research programme perform research activities in logistics, transport, and energy in strong connection with logistics and port-related companies, providing an interdisciplinary approach to the challenge of present-day freight transport.

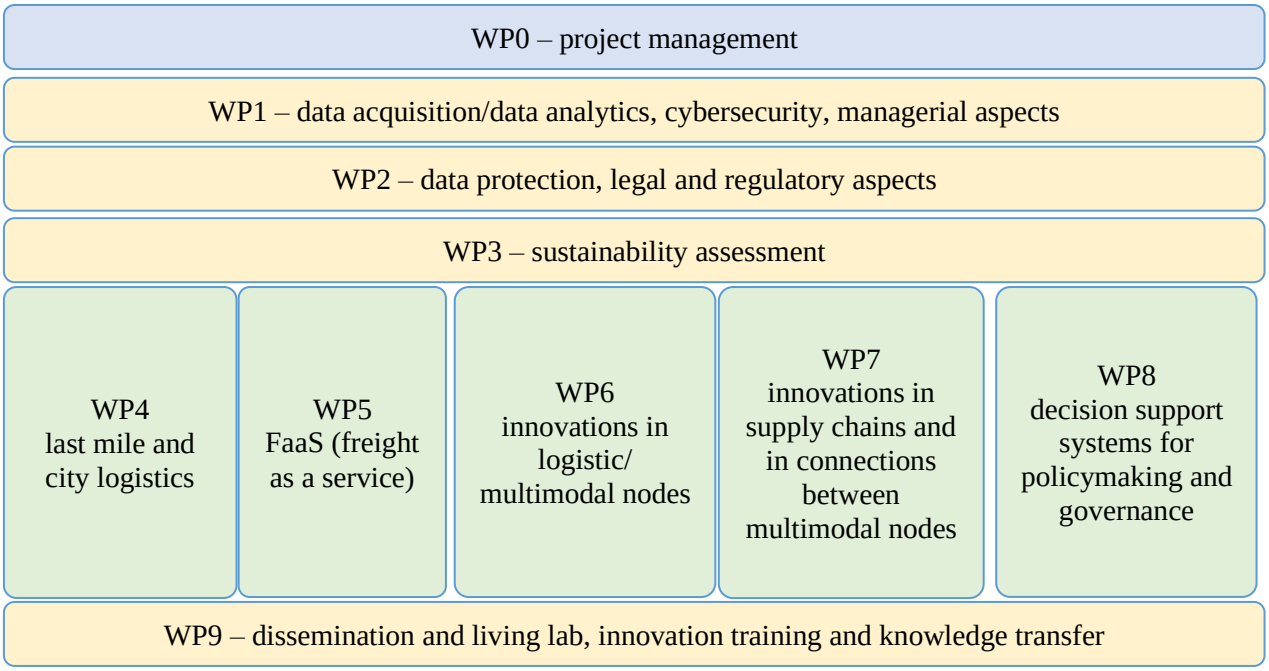
Università di Cagliari (UNICA). UNICA is a public research University and the largest Higher Education Institution in Sardinia, Italy. UniCA counts more than 25,000 students, dozens of B.Sc. and M. Sc. programs, 15 PhD programs, 35 specialization schools, more than 900 academic staff and about the same number of administrative staff. UniCA is organized in 15 Departments and 8 Centers. Overall, this complex organization is committed to achieve the University primary goals in research, teaching and third mission, respectively (i) by offering a diverse set of multi-disciplinary education programs, (ii) by performing cutting-edge interdisciplinary research, and (iii) by developing a sustained action toward technology transfer and meeting societal needs of local stakeholders. UniCA, through its international relations sector, promotes the participation in international research programs and as well as the scientific and technological collaboration with foreign universities and institutions. At present, it is active in: EU Framework Programs; several joint initiatives (such as Eranet, Prima, AAL, IMI2); NIH research projects; cooperation projects such as Interreg, ENI CBC MED, Life and EuropeAid.

Università di Pisa (UNIPI). UNIPI has a strong competence in logistics, freight transport, information processing systems with leading expertise in many crucial sectors for the Spoke: transport engineering, logistics and supply chain management, operations research, economics and management, law, distributed processing, cybersecurity, and artificial intelligence. A track record of projects, fundings, and international collaborations has been established in each of these domains, as well as a consolidated network of interactions with relevant local and national stakeholders and enterprises. UNIPI will leverage the CrossLab "Industrial IoT and Cloud Computing, Big Data & Cybersecurity" for the experimental activity and Polo Sistemi Logistici for interactions with local private and public stakeholders such as the North Tyrrhenian Port Network Authority.

3. PROJECT WPs STRUCTURE

The project of the Spoke is articulated in ten work packages (WPs), illustrated in the flowchart below. Aside from project management, four cross-WPs deal with transversal aspects (data acquisition and data analytics;

cybersecurity, data protection, legal and regulatory aspects; dissemination and living lab) and five vertical WPs deal with specific research tasks.



Research activities of the Spoke, illustrated in Section 2, match the structure of WPs, with a breakdown by WP task with involved participants as follows:

- **WP0 – project management (owner: UNINA)**
- **WP1 – data acquisition/data analytics, cybersecurity, managerial aspects (owner: UNIPI)**
  - WP1.1 Cloud-/edge-based data acquisition and processing (UNIPI, UNIGE)
  - WP1.2 Advanced Artificial Intelligence and Explainable Artificial Intelligence (UNIPI, UNIGE)
  - WP1.3 Blockchain-based security architecture and solutions for Logistic 4.0 (UNIPI)
  - WP1.4 Managerial aspects (UNIPI, UNIPARTH)
- **WP2 – data protection, legal and regulatory aspects (owner: UNINA)**
  - WP2.1 Legal and regulatory aspects (UNINA, UNIPI)
- **WP3 – sustainability policy and tools assessment (owner: POLIMI)**
  - WP3.1 Innovative approaches towards sustainability assessment at logistics nodes (POLIMI, UNIPI, UNICA)
  - WP3.2 Policies and nudging for sustainability in logistics and freight transport (UNINA, UNICA)
  - WP3.3 Corporate governance and sustainability-related disclosure (UNIPI)
- **WP4 – last mile and city logistics (owner: POLIMI)**
  - WP4.1 City logistics-as-a-service (UNINA, UNIGE, UNICA)
  - WP4.2 Multi-objective strategical/tactical/operational optimisation of freight distribution (UNIPI, UNINA, POLIMI, UNIGE, UNICA)
  - WP4.3 Innovative urban freight distribution modes: green vehicles and drones (UNIPI, UNINA, POLIMI)
  - WP4.4 Innovative urban freight distribution schemes and management operational strategies (UNIPI, UNINA, UNICA)
- **WP5 – FaaS (freight as a service) (owner: UNIGE)**
  - WP5.1 FaaS concept and implementation (UNINA, UNIGE)
  - WP5.2 Business models (UNINA, UNIGE)
  - WP5.3 Service network design: optimization models and methods (UNIPI, UNIGE)
- **WP6 – innovations in logistic/ multimodal nodes (owner: UNIPI)**

    - WP6.1 real-time, dynamic optimisation of multimodal node operations (UNINA, UNIPARTH, UNIGE)
    - WP6.2 innovation and energy efficiency at logistic nodes (POLIMI, UNIGE)
    - WP6.3 electric vehicles in large warehouses (UNIPI, UNIGE)
    - WP.6.4. strategic, tactical, operational planning in ports and intermodal terminals (UNICA, UNIGE)
- **WP7 – Innovations in supply chains and in connections between multimodal nodes (owner: UNIPARTH)**
    - WP7.1 Efficient and sustainable supply chains (UNIPI, UNIGE, UNICA)
    - WP7.2 Synchronization of logistics activities enabled by 4.0 paradigm (POLIMI)
    - WP7.3 Innovation in sea-land multimodal operations (UNINA, UNIGE, UNIPARTH)
    - WP7.4 Smart logistics dynamics (UNIPARTH)
- **WP8 – decision support systems for policymaking and governance (owner: UNINA)**
    - WP8.1 Public-oriented monitoring of freight transport and logistic systems (UNINA)
    - WP8.2 Decision support systems for policymaking and infrastructural planning (UNINA, UNIPARHT)
- **WP9 – dissemination and living lab, innovation training and knowledge transfer (owner: UNICA)**
    - WP9.1 Innovation training, active learning, knowledge transfer, preparation of guidelines (all partners)
    - WP9.2 Human factors and innovative simulators (UNICA, UNIGE)
    - WP9.3 Performance assessment of tasks and dissemination (all partners)
    - WP9.4 Virtual and on-site Living Lab (all partners)