Joint action plan for intermodal and multimodal passengers transportation from/to ports and airports

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Introduction

The present report is the third deliverable of WP3 of the Green and Intermodal Solutions for Adriatic Ports and Airports “ADRIGREEN” project. ADRIGREEN is a project under the INTERREG V-A Italy Croatia CBC Programme 2014-2020.

With the first deliverable under WP3, the Adrigreen team of Marche Polytechnic University collected and analyzed replicable operational and technological solutions aimed at improving intermodal connections and reducing the environmental impact of airports and ports.

A literature review was performed about existing solutions and case studies implemented at airports and ports. A Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis was performed for the existing solutions.

Whenever relevant to the present report, the information related to the SWOT-strategies section of the first deliverable of WP3 were considered for the evaluation of Strengths/Weaknesses, and Opportunities/Threats of the action. The general/literature SWOT approach applies to the structure of the SWOT-strategies section of the present report, the main general rules being the ones that follow.

- “MATCH Strengths and Opportunities”. Use internal Strengths to take advantage of external Opportunities.
- “OPPOSE Strengths to Threats”. Use internal Strengths to minimize external Threats.
- “OPPOSE Opportunities to Weaknesses”. Improve internal Weaknesses by taking advantage of external Opportunities.
- “DISRUPT Weaknesses and Threats”. Work to eliminate internal Weaknesses especially to avoid external Threats.
- “CONVERT Weaknesses into Strengths” Apply best practices aiming at turning Weaknesses into Strengths.
- “AVOID converting Strengths into Weaknesses”. Prevent wrong approaches that may convert Strengths into Weaknesses.
- “CONVERT Threats into Opportunities”. Move towards strategic directions that may convert Threats into Opportunities (scenarios turning Threats into Opportunities)
- “AVOID converting Opportunities into Threats”. Prevent inadequate planning that may convert Opportunities into Threats (scenarios turning Opportunities into Threats).

Adrigreen partners provided basic information in order to perform a SWOT analysis dedicated to the possible actions to be implemented. We would like to stress the fact that A4 airport was not supposed to carry out data collection for environmental analysis and they did not receive any funding for this task. However, they voluntarily performed environmental data collection to help the Adrigreen team of Marche Polytechnic University. We really appreciated it and we would like to thank the Adrigreen team of A4 Airport once more for their support.

For the environmental assessment of the Adrigreen airports and ports reported in the second deliverable, the investigated topics included multimodality.

Within this document, a series of pilot actions is presented based on the information collected in the first deliverable and on the environmental benchmarking reported within the second deliverable. As a general rule, we scrutinized relevant pilot actions belonging to two groups.

The first group is made of all the proposals presented within the first deliverable i.e., the possible applicable pilot actions collected within the relevant literature and/or case studies. The pilot actions were chosen according to their applicability within the scope of the project following the SWOT analysis and the results of environmental assessment/benchmarking. Due to such benchmarking and SWOT analysis, a single pilot action may be suitable either to all the ports and/or the airports or to some of them only.

The second group is made of pilot actions deriving directly from the scrutiny of environmental assessment performed over Adrigreen port/airports as reported in deliverable two, including the related SWOT analysis. In this case, indicators showed how one or more partners “behave” better in a specific environmental field. A subsequent analysis let us understanding the local actions implemented so to reach such results and to identify the proper pilot actions to be realized within Adrigreen project. Quite obviously such actions are applicable to some of the partners only.

The environmental analysis performed outlined that the environmental footprint of the Adrigreen airports and ports could be reduced (thus improved) by applying actions regarding sustainable transportation of passengers from/to the airport/port infrastructures.

Greenhouse gases emissions deriving from airport and port infrastructures can also be considered as a general proxy variable for airborne pollutants emissions. As a very general rule, lower greenhouse gases emissions will also mean lower airborne pollutant emissions. Therefore, actions that result in reducing the carbon footprint of a given activity should also reduce the global and/or local emissions of air pollutants. For example, an action that cuts local fuel consumption (e.g., replacing fuel-driven vehicles with electric ones) has a positive impact on both greenhouse gas emissions (globally reducing them) and air pollutant emissions (virtually zeroing them locally and reducing them globally). However, care must be taken when analyzing the global and local impacts of an action since this rule is not always so straightforward.

The proposed actions are summarized in tables, each row outlining the following information:

- general action,
- specific short-term/long term action,
- metrics,
- applicability/status at each Adrigreen airport/port
- relationship with Strengths/Weaknesses at each Adrigreen airport/port
- relationship with Opportunities/Threats at each Adrigreen airport/port.

Most short-term initiatives require short/medium start-up times, minimal implementation and design complexity, and relatively low costs. All permission procedures can be usually managed directly by the airport/port authority or by the stakeholders involved. Long-term initiatives are characterized by prolonged start-up times and high complexity of design and implementation. Authorization procedures will mainly depend on local, regional, or national authorities/agencies.

For the applicability/status of each specific action, a range of values from 0 to 3 was considered as depicted in Table 1.

APPLICABILITY/STATUS	**DESCRIPTION**
0	NOT APPLICABLE OR NOT SUGGESTED
1	APPLICABLE AND SUGGESTED
2	PARTIALLY IMPLEMENTED
3	IMPLEMENTED

Table 1 Numerical indexes recapping the status of implementation of a specific activity at specific port/airport.

For the columns of the tables associated to the SWOT analysis, the potential interactions of each specific action with the Strengths/Weaknesses and Opportunities/Threats, highlighted by the Adrigreen partners, are summarised through numerical indexes. A4 Airport voluntarily took part to WP3 but did not provide SWOT analysis. Therefore, the Strengths/Weaknesses, and Opportunities/Threats columns were not filled for A4 Airport. For the Strengths/Weaknesses and for Opportunities/Threats, a range of values from -2 to 2 was considered as depicted in Table 2 and Table 3.

STRENGTHS/WEAKNESSES INDEX	DESCRIPTION
-2	The implementation of the specific action is expected to have minor or negative influence on the Strengths whilst boosting several Weaknesses of the airport/port.
-1	The implementation of the specific action is expected to have minor or none influence on the Strengths whilst boosting one or more Weaknesses of the airport/port.
0	The implementation of the specific action is expected either not to interact with Strengths and Weaknesses of the airport/port or to balance the related effects.
1	The implementation of the specific action is expected to boost one or more Strengths whilst having minor/no influence on the Weaknesses of the airport/port.
2	The implementation of the specific action is expected to boost several Strengths whilst having minor or positive influence on the Weaknesses of the airport/port.

Table 2 Numerical indexes recapping potential positive/negative synergies with Strengths/Weaknesses of a specific action at specific port/airport.

OPPORTUNITIES/THREATS INDEX	DESCRIPTION
-2	The implementation of the specific action is expected to have minor or negative influence on the Opportunities whilst boosting several Threats of the airport/port.
-1	The implementation of the specific action is expected to have minor or none influence on the Opportunities whilst boosting one or more Threats of the airport/port.
0	The implementation of the specific action is expected either not to interact with Opportunities and Threats of the airport/port or to balance the related effects.
1	The implementation of the specific action is expected to boost one or more Opportunities whilst having minor/no influence on the Threats of the airport/port.
2	The implementation of the specific action is expected to boost several Opportunities whilst having minor or positive influence on the Threats of the airport/port.

Table 3 Numerical indexes recapping potential positive/negative synergies with Opportunities/Threats of a specific activity at specific port/airport.

Steps for the pilot actions

1. Driving factors evaluated through a qualitative analysis such as a SWOT analysis and/or data collection for the assessment of the consumption trend and the environmental performance preceding the pilot action. Definition of key performance indicators.

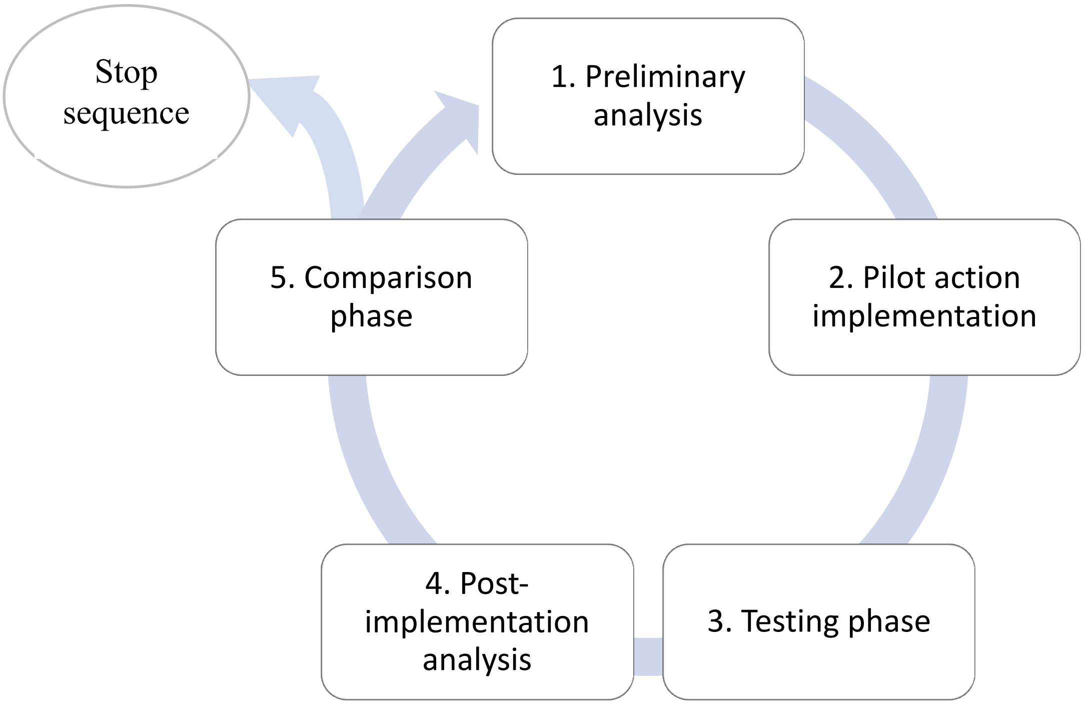
2. Identification of the pilot action to implement based either on the results of Benchmarking within Adrigreen partners or upon case studies reported by literature upon similar airport/port infrastructures.

3. Testing phase and collection of qualitative and/or quantitative data.

4. A qualitative analysis such as SWOT analysis and/or collection of data for the assessment of the consumption trend and the environmental performance resulting from the implementation of the pilot action. Evaluation of key performance indicators. Evaluation of the performance of the airport/ port infrastructure over time for internal benchmarking.

5. Comparison between step 1 and step 4 qualitative and/or quantitative data. If the desired performance levels have been reached, the sequence ends otherwise to reach the objectives it restarts from step 1.

Figure 1 Sequence to define and evaluate pilot action initiatives.



The main sections of this report cover the following issues:

1. Sustainable solutions for the transport of passengers from/to airport/port infrastructures
2. Annex: an example of the environmental analysis related to greenhouse gases and airborne pollutants emissions of a specific action.

Strengths, Weakness, Opportunities, and Threats analysis of Adrigreen airports

All the airports consider the location as Strength. Namely, A2, A3, A5, and A6 highlighted the proximity of the airports to the respective main urban centres while A1 highlighted its position within the region.

A common Strength of A1, A5, and A6 is their minor environmental disturbance, A5 and A6 also reporting good communication and coordination with the public administrations and other stakeholders involved in the management of environmental issues.

Another Strength of A5 and A6 is public transport, with frequent train calls for A5 and frequent bus calls for A6.

A1, A3, and A6 have tourist attractions nearby and serve a significant number of tourists.

Both A1 and A2 report likelihood of infrastructure enlargement. The current infrastructure of A2 was designed to serve about 3 to 5 times the present passenger traffic.

Traffic congestion of the access roads is a common Weakness of A5 and A6 and a potential Weakness of A2. Seasonality of passenger traffic is a Weakness both for A1 and A6 airports, whereas incoming touristic activities are not well developed at A3 Airport.

A2 Airport reported limited public-transport connections. Similarly, A5 Airport reported insufficient rail connections to some destinations of the area and no direct connection with the nearby port.

Investments for enhancing public transportation may represent a Threat for A3 and A6 airports. Urban planning and ownership of surrounding properties may pose a Threat to the potential expansion of A1 and A2. Coordination with involved stakeholder may pose a Threat to development of integrated tariff system and information at A5 Airport.

'A1' Airport – SWOT analysis

Strengths	Weaknesses
- Fully operational airport; - Minor environmental disturbances; - Land available for expansion; - Geographical location in the region; - Regional state support; - A small number of competitive airports for the region; - Large volume of receptive tourism; - Dependence on "external" gross domestic product (GDP) growth.	- Absence of domicile carrier; - Seasonal international traffic; - A small amount of cargo; - Limited population that would increase the output potential; - Marketing activities (tour operators) generally reach the norm in the "main" season; - Dependence on "external" GDP growth.
Opportunities	**Threats**
- Potential for GDP growth dependent on GDP; - Attracting new airlines (airline marketing); - Introduction of cruise and summer systems; - Potential receptive tourism (cooperation with tour operators) outside the "main" season; - Development of non-aviation activities (hotel, offices, advertising, car parking, etc.)	- Poor development in the tourism sector will reduce the window of Opportunity for airport development; - Danger of continued instability of the main target markets (northern European and ex EU countries); - Ownership of surrounding land.

‘A2’ Airport– SWOT analysis

Strengths	Weaknesses
- The airport is designed to serve up to 1 million passengers in its current configuration; - A quite large airport area with possibilities of expansion both in terms of passenger traffic, but especially cargo traffic; - Proximity to the main urban centres of two different provinces.	- Road connections are barely sufficient to manage current airport traffic, an increase in both passenger and cargo traffic must necessarily re-evaluate the access points to the infrastructure; - Collective public transport to connect the airport to nearby cities is still limited; - Incoming traffic is much higher than outcoming.
Opportunities	**Threats**
- The nearby area attract several forms of tourism (sports, congress, seaside, archaeological, food and wine and shopping); - The development of regional tourism projects of all kinds, especially with the countries of Eastern and Northern Europe, would increase airport traffic; - Possible enhancement of cargo, with the arrival of a multinational company centre less than 15 km away and the presence of a strong industrial presence in the nearby hinterland.	- Very populated area towards the sea makes expansion in that direction almost impossible; - Two large or medium/large airports within 150 km and one small airport within 50 km offer similar services with good connections which reduce the potential catchment area of the airport; - Long dialogues with the Province and the Region to have support for the development (including eco-sustainable) of the airport; - With the recent modernization of the highway and the high-speed rail network, the domestic traffic comes mainly by wheel or rail.

‘A3’ Airport – SWOT analysis

Strengths	Weaknesses
- Strong financial backing from Regional Government; - Non saturated capacity available for growth; - Small flexible organization; - Sound financials; - Closeness to city centres and easy access from highways; - Good touristic attractiveness (sea, mountains).	- Low awareness on the international markets; - Size still insufficient for full financial independency; - Low level of non-aviation revenues, especially from parking; - Incoming tourism activities not well developed; - Nearness of Rome airports served through highway.
Opportunities	**Threats**
- Attractiveness for airside business (hangars, new airline base); - Good relationship with largest low-cost carriers for promoting strong growth; - New real estate contracts from Regional entities.	- Further growth of Rome; - Investment on rail service to Rome; - Region gross domestic product growth.

‘A5’ Airport – SWOT analysis

Strengths	Weaknesses
- Proximity to the city; - Rail connection with the provincial capital; - There are no criticalities with the public administration and/or the local population of the nearby municipalities for noise, etc.	- Traffic congestion on the road to access to the airport; - Inefficient railway connection with different main towns of the nearby area; - No direct connection with the port.
Opportunities	**Threats**
- The region is a rapidly expanding touristic area; - The airport managing body has a great know-how as it manages several airports; - Expansion of the parking offer, including rental cars; - Rationalization of airport-station-port bus services; - A new "Flixbus" stop at the airport.	- Uncertain timing for the construction of the new highway tollbooth and dedicated roads; - Resistance on the part of transport operators towards an integrated tariff system and information; - Currently, the COVID emergency prevents the planning of business aviation.

'A6' Airport – SWOT analysis

Strengths	Weaknesses
- The tourist attractiveness of the region, and in particular the area served by the Airport, is constantly increasing; - Proximity to the city and its port; - There are no criticalities with the public administration and/or the local population of the nearby municipalities for noise, etc; - Presence of a direct and frequent bus connection between the airport, the railway station and the port; - Presence of direct and frequent bus connections with the nearby city.	- High parking occupancy rate; - Seasonality of the demand; - Traffic congestion on the access roads to the airport (in particular the arrivals area) in some time slots.
Opportunities	**Threats**
- Expansion of parking spaces; - Construction of the new railway connection with A6 Airport, which allows the offer of direct connections with the main regional destinations, in particular the regional capital, and nearby main cities; - A new Flixbus stop at the airport.	- Lack of funds to finance the enhancement of local public transport services.

Strengths, Weaknesses, Opportunities, and Threats analysis of Adrigreen ports

P1, P2, and P3 are listed among the trans-European transport network (TENT-T) maritime ports. Ancona is recognised as core port within the Scandinavian-Mediterranean Corridor, while Pula and Dubrovnik are comprehensive ports.

As a general remark, Pula port has its strategic asset in leisure maritime activities, while Dubrovnik port is a very important port for cruises calling the Adriatic Sea. Also, it has local ferries connecting the port to the main Croatian island.

Ferries connecting the Doric shores to Croatia, Albania, and Greece, are the strategic asset of the port of Ancona, both in terms of passengers and freight flows. Furthermore, the port of Ancona is a multipurpose port, thanks to the presence of different maritime activities having an increasing role in the development of Marche Region economy, generating nearly 2.7% of regional GDP.

A common Strength of P1 and P3 is their geographical location. A system has been implemented by P2 port for quality management and environmental management protection based on standards.

A common Strength of P1, P2, and P3 is the proximity of their port to the city centre. This represents also a common Weakness, because the port activities can affect the quality of life of the people living nearby the port area. The environmental footprint of ports includes emission of airborne pollutants and greenhouse gases, noise, water, and soil pollution.

For example, port shipping and ground movements were reported to contribute to the yearly average ambient levels of PM_{10} (19%), NO_2 (25%) and SO_2 (43%) of the nearby city by the Tyrrhenian Sea (Gobbi et al. 2020). Based on AERMOD simulations, Fileni et al. (2019) have observed that port activities strongly influence the local air quality.

Long term exposure to airborne pollutants has been recognized as a factor causing adverse health effects (WHO 2013). Long term effects on mortality were reported by Bauleo et al. (2019) for the residents in the proximity (<500 m) of an Italian port, with higher risk of mortality from lung cancer and all cancers.

A common Weakness is represented by the lack of regular data collection and environmental monitoring.

Both P3 and P2 ports have structural barriers for the production and use of renewable energy sources.

The availability of EU financial instruments is a common Opportunity of the three ports. Moreover, the three ports are active in international projects aimed at building new infrastructures, improving accessibility, operations management, and environmental protection.

A common Threat of the three ports may be the need for large investments for new infrastructures.

A Threat reported by P1 port is the Lack of a dedicated road infrastructure with the consequence of road congestion during disembarking.

Threats for P2 port are the environmental externalities deriving from an increase in ship calls and lack of communication and coordination between institutions and other stakeholders involved in environmental protection.

P3 port considers a Threat collecting and analysing data for the application of green and sustainable technologies.

'P1' port – SWOT analysis

Strengths	Weaknesses
- The port, embedded in the Ports Authority system, has a strategical geographic position for the ferry traffic: nearly 19% on the international ferry passenger traffic of the national ports embark and/or disembark in the port, as it has a competitive transit time to Balkan countries and Greece; - The port has daily departures for Greece and it is the main national port on the Italy-Croatia ferry traffic. It has also a regular line to Durres; - Concerning the TEN-T European transport policy, the port is recognised as core port within the SCAN-MED corridor, a crucial north-south axis for the European economy.	- The port is very close to the city centre, as it is an historical port, embedded in the urban context; - Therefore, the port promoted the signature of the "Blue Agreement", with the aim to reduce the sulphur content of maritime fuel for the companies willing to commit to it, contributing to the environmental sustainability of the port; - In addition, to face to the increasing need of additional areas to be dedicated to port activities, the Ports Authority is rationalising and upgrading the existing infrastructures, adapting it to the new needs.
Opportunities	**Threats**
- Thanks to recent road infrastructure improvements, the port is a gateway to reach Eastern Balkans also for passengers coming from inland area, increasing its catchment area; - Furthermore, territories surrounding the port are very attractive from a tourist point of view, making the port very competitive for cruise companies. Thus, the Ports Authority is going to realise a new quay and cruise terminal, to strengthen the role of the port in the cruise market; - In addition, the port is a multipurpose port, where different maritime sectors contribute to its competitiveness on the international stage (passengers and freight traffic, high quality mechanical engineering, fishing sector, logistics, and tourism).	- The port lacks a dedicated road infrastructure to connect it to highways. This is a quite sensitive issue, as the port is a leader in ferry transport. So far, tracks and trailers pass through a densely populated area to join highway, creating also congestions in urban roads, especially during disembarking; - However, the technical - economic feasibility project for the construction of a dedicated link between the Port and the national main roads has been approved; - This will ensure a smooth connection between land and sea infrastructures, essential to guarantee the future competitiveness of the port.

‘P2’ port – SWOT analysis

Strengths	Weaknesses
- Available programmes and technological documents for environmental management of port according to the national, European and International environmental legislation; - Basic administrative structures created at the local level for implementation and enforcement of environmental legislation; - Change in structure of passenger transport turnover in port (e.g., increase of homeport and Ro-Ro traffic leading to decrease of the unhealthy impact of cruise transit ships on environment in port area); - Initiatives of port authority taken to protect the environment (e.g., implementation of a project regarding environmental monitoring); - Communication policy and practice for informing the society about initiatives taken to protect the environment; - There is the certified plan by the International Code for Security of Ships and Port Facilities (ISPS Code), establishing a system for quality management and environmental management protection based on standard ISO 9001/2015 and ISO 14001/2015.	- Lack of facilities for the use of renewable energy sources; - Lack of facilities for onshore power supply (cold ironing); - Lack on energy efficiency of handling equipment (e.g., electrification, energy recovery); - Low sulphur fuel availability; - Lack of self-monitoring system for particular components of the environment; - Limited internal financial resources to ensure environmentally sound operation of the port.
Opportunities	**Threats**
- No nearby industry to the port; - Establishment of the administrative structure for the implementation and enforcement of environmental legislation; - Availability of EU financial instruments in order to ensure a support to operations management processes aimed at environmental protection in the port area; - Increased demands for protection of the environment in the area around the ports in order to develop priority sectors for the country; - Availability of EU financial instruments for support of EU port; - Operations management and environmental protection (e.g., participation in international projects).	- Low environmental consciousness; - Resisting bad practices; - Slow implementation of new legislation; - Lack of communication and coordination between institutions and other stakeholders responsible for implementing environmental legislation; - Expected increase in ship call in the ports, which is a potential danger to environmental protection.

‘P3’ port – SWOT analysis

Strengths	Weaknesses
- Advantageous geographical location.	- Monitoring of the port and collection of data is bad and incomplete; - Environmental laws poorly implemented; - Infrastructure does not support the transition to sustainable energy sources; - No renewable energy resources are used; - Poor waste-water management.

Opportunities	Threats
- Use of European Union funds; - Investment in new infrastructure (e.g., wastewater treatment plant); - Improving accessibility; - Investment in new green maintenance equipment; - Learning from other ports how to reduce waste; - Learning from others with the aim of raising the quality of service and maintenance.	- Large investments; - Legislation that poorly supports self-sustainable development; - Collecting and analysing data for the application of new technologies that enable the use of renewable energy sources and the sustainable development of the port.

Sustainable transportation of passengers from/to airport/port infrastructures

According to a report about transport development by Republic of Croatia (2017), cars are the most popular means of transportation with about 51% of all trips (40.8% as a driver and 10.4% as a passenger), followed by walking 30% and public transport (bus, tram, train, and ferry) 12%.

Maritime transport is fundamental for the connection of Croatian mainland and islands. The improvement of links between maritime public transport and local public transport represents an opportunity both for domestic and international passengers.

The monthly distribution of passengers in Croatian airports shows a seasonal trend with the highest volume of passengers in July and August and the lowest in February. This seasonal trend is due to the volume of passengers on international flights within the touristic season, whereas the volume of passengers on domestic flights is quite steady throughout the year (Republic of Croatia 2017). Therefore, the initiatives aimed at improving sustainability of transport modes to/from airports may be tailored for the different types of passengers. A very similar situation almost certainly occurs at Italian Adrigreen airports.

Table 4 (adapted from Transport development strategy of the Republic of Croatia (2017 – 2030), Republic of Croatia 2017) shows the estimated share of transport modes in the access to Dubrovnik and Pula airports. Railway or tram connections are not available at any Croatian airport.

Airport	Bus	Car	Taxi
Dubrovnik	35%	33%	32%
Pula	28%	40%	32%

Table 4 Estimated modal split in the access to airports according to the transport offer.

In Italy, the demand for local public transport showed a decrease of about 2% between 2014 and 2016 (ISPRA 2018).

Between 2014 and 2016, the city of Rimini confirmed the national trend, with a decrease of about 5% in in the demand for local public transport. In contrast, the demand for local public transport increased in Ancona (about 4%), Bari (about 21%), Brindisi (about 15%), and Pescara (about 1%). Figure 2 shows the number of passengers per year vs. number of inhabitants of the municipality for the five Italian cities considered within this study.

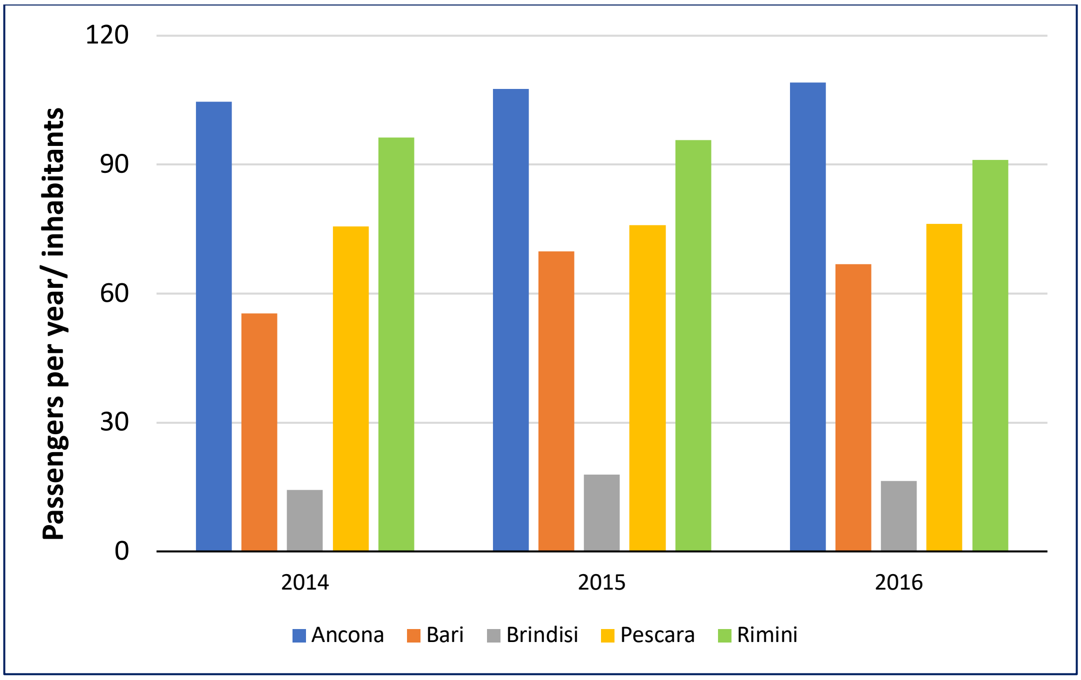


Figure 2 Demand for local public transport in the provincial capital municipalities of Ancona, Bari, Brindisi, Pescara, and Rimini (Italy). The values were estimated for Rimini for the years 2014–2016 and for Pescara for the year 2016. Own elaboration based on data from ISPRA 2018.

It is important to notice and take into account that the choice of mobility indicators may affect the comparison between public transportation systems of different cities. For example, Table 5 (adapted from Pinna et al. 2017) shows different rankings of three Italian cities that arise from considering two different indicators.

Indicator [unit]	Note	Ranking
Bus network density [km/km2]	Extension of the network vs. area under the jurisdiction of the municipality	Bari> Rimini> Ancona
Demand for public transport [passenger/y/inhabitants]	Number of passengers per year vs. number of inhabitants of the municipality	Ancona> Rimini> Bari

Table 5 Ranking of public transport indicators for the cities of Ancona, Bari, and Rimini in 2015.

Between all the solutions to boost and ease public transportation and intermodality, infomobility systems are information and communication technology systems such as variable message panels that display real-time traffic information at public transport stops, indication of routes and waiting times, websites serving public transport users and travel planning applications, electronic ticketing systems and/or online sales of public transport tickets, etc. Infomobility systems represent an option to let passengers easily plan and experience their travel. In 2013, infomobility systems were operating at Ancona, Bari, and Pescara (ISTAT 2014).

According to a survey edited by European Environment Agency (EEA 2019), almost all the airports (namely 98%) are served by public transportation systems. However, the majority of airports' employees and travelers do not use public transport to reach the workplace (EEA 2019). The emissions related to surface access to the airport infrastructure are on-site emissions deriving from non-airport-operator owned sources (ACI 2018). For ports, the emissions deriving from the modes of transportation utilized by the employees are "other indirect sources" under Scope 3 (Azarkamand et al. 2020).

The development of improved public transportation systems aims at discouraging the use of private cars providing travelers with fast, environmental-friendly and cost-effective transport solutions. This requires a joint effort of port/airport management and local stakeholders as well as a more positive attitude towards public transport.

Table 6 (adapted from a work by Reichmuth 2010) shows public and private ground access modes to airports or ports. Other actions aimed at improving the sustainability of transportation in the airport infrastructures were recently reported in a work by Greer et al. (2020).

Transport means	Description	Pros and Cons
Car	Own car parked at port/airport	Parking fees represent an important revenue especially for airport operators.
	Kiss-and-ride	No parking fees; Generates pollution and GHG.
	Rental car	Revenue for airport operators deriving from the rent of offices and parking spaces.
	Taxi	Maximum flexibility; Generates pollution and GHG.
Rail	Both short and long distances	No traffic jam, high capacity; Rail service may increase the catchment area of the airport/port; Waiting time may be reduced for the travelers; Parking revenue may decrease.
Coaches	Long distance coaches	Long distance coaches in regions with less well developed rail network or none; Possibility of intermodal competition.
Bus	Public transport busses for short distances	Regular bus service; Travelers may associate bus service to traffic jam; Crowded place not suitable for carrying a luggage; Buses dedicated to airports/ports (express buses) with space for luggage; Higher fares for express buses.
GHG = Greenhouse Gases		

Table 6 Transport modes to access airports and ports.

Table 7 reports examples of pilot actions aimed at promoting sustainable mobility at ports/airports and the related SWOT analysis.

Table 8 summarizes relevant/reference case studies for actions aimed at promoting sustainable mobility from/to airport and port infrastructures.

Further, more-in-deep, analyses and proposals regarding multimodality at Adrigreen ports and airports will be presented in an addendum to the present report. In fact, we are now carrying out more studies concerning the short-term and long-term effects of Covid19 pandemic on public transport and multimodality.

Given that the partners already experienced new scenarios deriving from Covid pandemic crisis and the amount of literature describing new scenarios, we expect to perform the following actions before the end of the project.

- Further analysis of relevant literature regarding expected effects of Covid pandemic upon multimodal transportation in Adrigreen framework.
- Collection of new datasheets specialized to assess Covid Pandemic effects upon Adrigreen Partners
- Evaluation of environmental framework of new scenarios for Adrigreen partners and analysis of scenarios with Partners.
- Preparation of ad-hoc technical document to address possible new scenarios for Adrigreen Partners and other comparable players in the Adriatic area.

General action	Specific Short-Term Long-Term Action	Metrics	Applicable to	Status	Strengths Weaknesses (Index)	Opportunities Threats (Index)
Initiatives to foster sustainable mobility	Hotel and car rental shuttle bus consolidation to reduce the number of empty trips (STA)	GHG and airborne pollutants emissions	A1	1	2	2
			A2	1	2	2
			A3	1	1	0
			A4	1	N/A	N/A
			A5	1	2	2
			A6	1	2	0
			P1	1	1	1
			P2	1	1	1
			P3	1	1	1
Initiatives to foster sustainable mobility	Infomobility (LTA)	Customer satisfaction; Demand for public transport	A1	1	2	1
			A2	1	2	-1
			A3	1	1	0
			A4	1	N/A	N/A
			A5	1	2	0
			A6	1	2	2
			P1	1	2	2
			P2	1	2	2
			P3	1	1	1
Initiatives to foster sustainable mobility	Airport/port with an intermodal transport hub (LTA)	Customer satisfaction; Demand for public transport	A1	1	1	0
			A2	1	0	-1
			A3	1	2	1
			A4	0	N/A	N/A
			A5	2	1	1
			A6	1	1	1
			P1	1	1	1
			P2	1	1	1
			P3	0	1	1
Initiatives to foster sustainable mobility	Electric buses (LTA)	Electricity consumption (kW); GHG and airborne pollutants emissions	A1	1	1	0
			A2	1	0	-1
			A3	1	2	1
			A4	1	N/A	N/A
			A5	1	0	1
			A6	1	1	-1
			P1	1	2	1
			P2	1	2	1
			P3	1	1	1
Initiatives to foster sustainable mobility	Airport/Port-rail intermodality train to plain/ship (LTA)	Customer satisfaction; Demand for public transport	A1	0	N/I	N/I
			A2	1	2	0
			A3	0	N/I	N/I
			A4	0	N/A	N/A
			A5	1	2	1
			A6	0	N/I	N/I
			P1	1	2	2
			P2	0	N/I	N/I
			P3	1	2	1
N/A = Not Applicable; N/I = Not Implementable mostly due to lack of infrastructures; LTA = Long Term Action; STA = Short Term Action; GHG = Greenhouse Gases						

Table 7 Actions aimed at promoting sustainable mobility in airports and ports.

General action	Specific Action	Metrics	Reference case studies
Initiatives to foster sustainable mobility	Hotel and car rental shuttle bus consolidation to reduce the number of empty trips	GHG and airborne pollutants emissions	Nanjing Lukou International Airport (Bao et al. 2018).
Initiatives to foster sustainable mobility	Infomobility	Customer satisfaction, demand for public transport	Athens International Airport (Panou et al. 2007); Municipality of Ancona under the INTERREG project E-CHAIN (web site of INTERREG).
Initiatives to foster sustainable mobility	Airport/port with an intermodal transport hub	Customer satisfaction	Web site of Trieste Airport.
Initiatives to foster sustainable mobility	Electric buses	Electricity consumption (kW); GHG and airborne pollutants emissions	Web site of Schiphol Airport; Web site of Brussels Airport.
Initiatives to foster sustainable mobility	Airport-rail intermodality: from train to plain; Port -rail intermodality: from train to ship	Customer satisfaction	Vienna Schwechat Airport (Website of ÖBB).
GHG = Greenhouse Gases			

Table 8 Airport and port reference case studies for actions aimed at promoting sustainable mobility.

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Annex: Example of environmental analysis

Switching from fossil fuel to electric vehicles: comparisons of airborne pollutants and CO2 emissions

Emissions of airborne pollutants (NOx and PM) and CO2 deriving from the operation of diesel vehicles

For diesel vehicles, the emissions of Nitrogen Oxides NOx, Particulate Matter PM, and Carbon Dioxide CO2 were evaluated following Tier 1, according to Ntziachristos et al. (2019), as follows:

$$E_i = \sum_j EF_{ij} \times FC_j \times U_l \tag{1}$$

where E_i is the emission value of NOx [g], PM [g], or CO2 [kg]; EF_{ij} is the emission factor specific for the type of fuel and the vehicle category (Table 9), [g/kg fuel] for PM and NOx; [kg CO2/kg fuel] for CO2; FC_j is the fuel consumption related to the j-category of vehicle (Table 10) [g/km]; U_l is the usage per year for the l-vehicle (Table 11), [km/year]. All such tables are adapted from Ntziachristos et al. (2019).

Category	Fuel	Airborne pollutants including CO2	Unit of emisison factor	Emission factor
Passenger cars	Diesel	NOx	g/kg fuel	12.96
Passenger cars	Diesel	PM	g/kg fuel	1.10
Passenger cars	Diesel	CO2	kg/kg fuel	3.169
Light commercial vehicles	Diesel	NOx	g/kg fuel	14.91
Light commercial vehicles	Diesel	PM	g/kg fuel	1.52
Light commercial vehicles	Diesel	CO2	kg CO2/kg fuel	3.169

Table 9 Tier 1 emission factors for diesel passenger cars and light commercial vehicles.

Vehicle category	Typical fuel consumption [g/km]
Light commercial vehicles	80
Passenger cars	60

Table 10 Tier 1 typical fuel consumption per km, by category of vehicle.

	Vehicle category	Usage [km/year]
Diesel	Light commercial vehicles	*For example: 30,000*
Diesel	Passenger cars	*For example: 15,000*

Table 11 Mileage per year of the vehicles that are going to be replaced during port/airport operations.

More in general, the environmental footprint of each vehicle or any other device operating by an internal combustion engine, can be evaluated introducing two or three parameters along the lines of the above analysis. When dealing with two parameters only, one of them is the so-called "activity indicator" (e.g., km/year, usage hours/year, kg of fuel/year) while the other one is the related emission factor (e.g., g of CO2 per km, g of CO2 per hour, g of CO2 per kg of fuel). When using three parameters, the third one usually links the activity indicator to a more generic emission factor. For example, the generic emission factor g of CO2 per kg of fuel can used either if we know the actual fuel consumption or by assessing its amount by means of a third parameter such as fuel consumption per km or fuel consumption per hour of operation.

Emissions of CO2 deriving from the operation of electric vehicles

Local emissions of airborne pollutants is assumed to be null for the electric vehicles. This is not true, as already outlined, for Particulate Matter since an electric car still emits them due to wear of mechanical parts, brakes, and tires. At the moment such emissions have not been adequately measured for electric vehicles, so it is impossible to calculate them. On the other hand, emissions of airborne pollutants and CO2, due to the production of electricity and the related technology, should be taken into account.

For each electric vehicle, the CO2 equivalent emission (E_i) is evaluated as follows:

$$E_i = \sum_j FC_{ij} \times EF_j \times T_i \quad (2)$$

where FC_j is electricity consumption related to the battery capacity of electric vehicles [kWh]; EF_{ij} is the emission factor of 397 g CO2eq/kWh that was determined for Italy in 2017 (Gestore Servizi Elettrici 2018); T_i is the number of battery charges per year for the *i*-vehicle, [-].
For the i-vehicle, the number of battery charges per year (T_i) is obtained as follows:

$$T_i = \frac{U_i}{R_i} \quad (3)$$

Where U_i is the usage per year for the *i*-vehicle (Table 12), [km/year]; R_i is the range of the *i*-type of battery reported by the manufacturer, [km].

Type of vehicle	**Model**	**Manufacturer**	**Engine power [kW]**	**Range* [km]**	**Battery capacity* [Wh]**	**Utilization each unit [km/year]**
Electric scooter	*e.g. Model1*	*e.g. Manufacturer1*	*e.g.* 0.3	*e.g.* 45	*e.g.* 473.6	*e.g.* 2,000
Electric bicyle	*e.g. Model2*	*e.g. Manufacturer2*	*e.g.* 0.25	*e.g.* 70	*e.g.* 360	*e.g.* 3,000
Electric pick-up vehicle	*e.g. Model3*	*e.g. Manufacturer3*	*e.g.* 10	*e.g.* 201	*e.g.* 19200	*e.g.* 10,000
Electric pick-up vehicle	*e.g. Model4*	*e.g. Manufacturer4*	*e.g.* 5	*e.g.* 135	*e.g.* 14400	*e.g.* 15,000

Table 12 Technical specifications and usage per year of the electric vehicles purchased to replace some fossil fuel vehicles.

Also, for electric vehicles or devices the assessment can be performed either using two parameters or three ones. In this case the activity indicator is still hours/year or km/year or simply kWhe/year, while the generic emission factor is, for example g of CO2 per kWhe. The amount of electricity consumed can be evaluated as above or with any other proper combination of activity indicators and the related consumption parameters.

Case study: variation in emissions of airborne pollutants (NOx and PM) and CO2 deriving from switching from diesel vehicles to electric vehicles

Pilot action: acquisition of electric vehicles to be used in place of diesel vehicles.

The purchase of electric vehicles would be under the pilot action field that concerns the reduction of energy consumption and environmental footprint. CO2 emissions can be considered as a proxy variable both for energy consumption and for other airborne pollutant emissions. This implies that lower CO2 emissions are likely combined with lower energy consumption and lower emissions of airborne pollutants. Of course, this assumption is absolutely wrong whenever lower CO2 emissions are due to the self-production or the purchase of "green electricity".

Fuel	Vehicle category	Mileage [km/year]
diesel	Light commercial vehicle	30,000
diesel	Passenger car	15,000
diesel	Passenger car	12,000
diesel	Passenger car	12,000

Table 13 Example of mileage per year of the diesel vehicles that are going to be replaced by an Adrigreen partner.

Calculations were done according equations 1-3 based on data reported in Table 13 and Table 14.

Veichle	Type of vehicle	Manufacturer	Number of units	Mileage per unit [km/year]	Engine power [kW]	Range [km]	Battery capacity [Wh]
Electric scooter	*Model1*	*Manufacturer1*	10	2000	0.3	45	473.6
Electric bike	*Model2*	*Manufacturer2*	10	3000	0.25	70	360
Electric pick-up vehicle	*Model3*	*Manufacturer3*	1	30000	10	201	19200
Electric pick-up	*Model1*	*Manufacturer1*	1	15000	5	135	14400

Table 14 Technical specifications and usage per year of the electric vehicles purchased to replace some diesel vehicles by an Adrigreen partner.

According to this case study, each year diesel vehicles emit about 7.8 times the CO2 released to produce the electricity absorbed by the substitute electric vehicles (Figure 3).

Local emissions of airborne pollutants such as NOx and Particulate Matter (PM) are assumed to be zero for the electric vehicles. However, as already stressed, the emissions of some pollutants, mainly greenhouse gases should be considered according to the location of the production site and on the technology used for producing electricity. Finally, also emissions due to wear of mechanical parts, brakes and tires of electric cars should be considered.

Anyhow, the use of diesel vehicles and machinery results for sure in much higher local emissions of CO2, NOx and PM (Figure 3 and Figure 4).

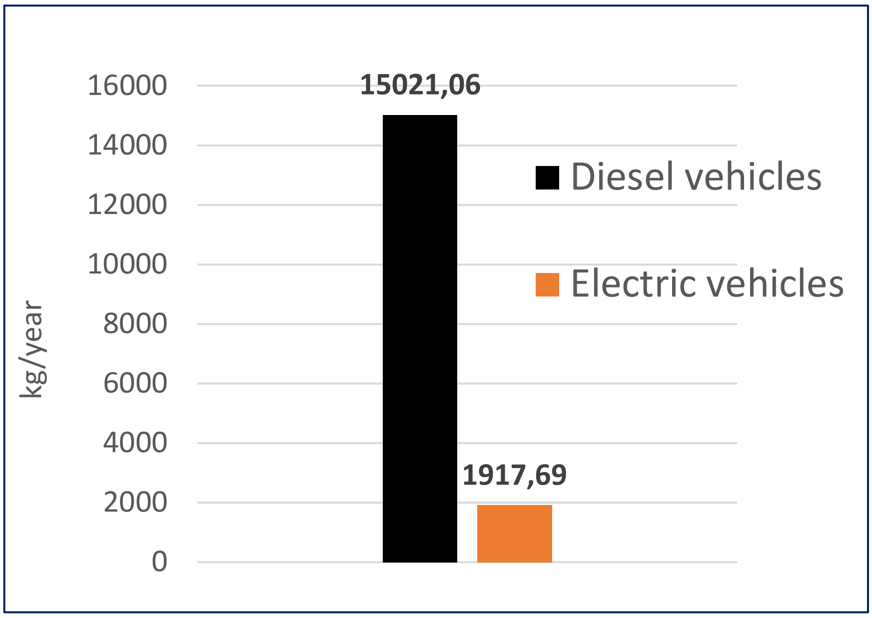

Figure 3 Comparison between greenhouse-gases emissions per year due to electric vehicles and the former diesel vehicles an Adrigreen partner.

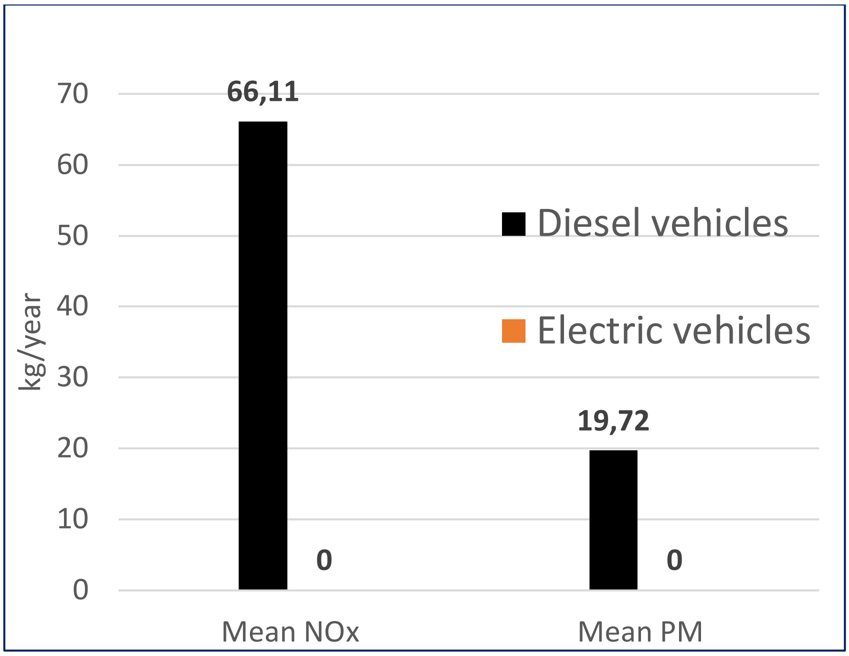

Figure 4 Comparison between local emissions per year of airborne pollutants (i.e., NOx and PM) due to electric vehicles and the former diesel vehicles at an Adrigreen partner. Emissions due to wear of mechanical parts, brakes and tires of electric cars were not taken into account.