Interreg Italy - Croatia ADRIGREEN

EUROPEAN UNION

Capitalisation report

Final version of 31/12/2021

Deliverable number D.3.1.1.

Index

Project Acronym	ADRIGREEN
Project ID Number	10044741
Project Title	Green and intermodal solutions for Adriatic airports and ports
Specific objective	4.1
Work Package Number	3
Work Package Title	Identification of innovative solutions and action plan definitions
Activity Number	1
Activity Title	Replicability: research and analysis of replicable operational and technological solutions
Partner in Charge	Marche Polytechnic University
Status	Final
Distribution	Public

Preface

Rising public environmental awareness and more stringent environmental framework conditions may put a stress on the environmental performances of port and airport infrastructures. However, the response from the port and airport managing authorities to a call for action may represent an opportunity to match a green image with reduction of operating costs of the infrastructures.

To avoid possible drawbacks, attention should be paid to the solutions embracing the whole complexity of the environment. The solutions that achieve a reduction of the carbon footprint of the infrastructure should aim at improving the quality of local environment, and vice versa. For example, the use of particulate matter filters reduces local pollution while the implementation of fuel saving technologies mitigates both local and global pollution.

The best practices or green technologies that are reported in the present study were retrieved from the internet. The focus of the research was on port and airport infrastructures that implemented smart sustainable solution to local and/or global environmental problems.

In the present study, the common strengths (S), weaknesses (W), opportunities (O), and threats (T) were considered for the infrastructures managed by Adrigreen partners.

The SWOT analysis consisted of internal and external factors playing a role in the performances of the transport infrastructures.

Structure of the report and methodologies

The solutions to improve the environmental performance of ports and airports are presented as follows:

- **Objectives;**
- **Case studies;**
- **Solutions;**
- **Possible improvements;**
- **SWOT strategies;**
- **Solution indicators.**

Objectives

Environmental goals that can be achieved implementing the solution.

Case studies

Examples of infrastructures implementing the solution.

Solution

Brief description of the solution with information regarding case studies.

Possible improvements

Weaknesses	Improvement
Main weaknesses according to the SWOT analysis of the infrastructures considered in the present study.	How the solution is expected to positively act on the weakness of the infrastructure.

Improvements are defined according to a qualitative scale ranging from no expected effect on the weakness, to an expected very high positive effect on the weakness.

Degree of improvement deriving from implementing the solution

Very high	There is high expectation of success in implementing the solution with respect to the weakness of the infrastructure.
High	The solution is expected to act efficiently on the weakness of the infrastructure.
Medium	Some effects are expected on the weakness of the infrastructure.
Low	Weak effects are expected on the weakness of the infrastructure.
Very low	Very weak effects are expected on the weakness of the infrastructure.
None	No direct effect is expected on the weakness of the infrastructure.

SWOT strategies

SWOT strategies are used to identify strategic directions, scenarios, and best practices related to environmental externalities deriving from operations at airport and port infrastructures.

Converting W into S	Best practices aiming at turning Weaknesses into Strengths.
Converting S into W	Wrong approaches may convert Strengths into Weaknesses.
Converting T into O	Strategic directions that may convert Threats into Opportunities. Scenarios turning Threats into Opportunities.
Converting O into T	Inadequate planning may convert Opportunities into Threats. Scenarios turning Opportunities into Threats.
Matching O to S	Scenarios that match Opportunities with Strengths. Best practices aiming at matching Opportunities with Strengths.
Avoid T and W	Scenarios that may match Threats and Weaknesses. Best practices aiming at minimizing Threats and Weaknesses.

Solution indicators

Each solution was assessed considering the following indicators.

Design complexity

The expected complexity for the design of the solution was evaluated according to the following indexes.

Very low	No planning is needed.
Low	Little planning is needed. The solution does not require planning permissions.
Medium	The solution requires a standard design. The solution may require permissions.
High	The solution requires a design. The solution requires authorizations.
Very high	Highly specialized design is needed. The solution requires authorizations.

Implementation complexity

The expected complexity of implementing the solution was evaluated according to the following qualitative indicators:

Very low	Very easy to implement solution. Quick-delivery solution. No specific expertise and skills are required.
Low	Easy to implement solution. Some deliverables can be achieved in a short period of time. Some specific expertise and skills may be required.
Medium	Project duration may be long. Some stakeholders may be involved. Specific expertise and skills may be required.
High	Project duration is long. Some stakeholders are involved. There is a need for monitoring and controlling. Specific expertise and skills are required.
Very high	Expected project duration is long. Many stakeholders are involved. High level of monitoring and controlling. Teams with a wide range of expertise and skills are required.

Implementation cost

Expected costs involved in the implementation of the solution were evaluated according to the following qualitative indicators

Very low	No need for investing in infrastructures. No need for investing in human capital. Example: campaign about green habits delivering flyers and gadgets to customers.
Low	No need for investing in infrastructures. Low-level investments in human capital. Examples: purchase of new machinery; workshops and training courses to engage the employees on sustainability.
Medium	Low-level investments in infrastructure. Low-level investments in human capital. Only basic changes in technology with no need for mutual adaptation of technology to the parties involved in the transport system.
High	Need for investing in infrastructures. Need for investing in human capital. Changes in technology impose mutual adaptation of technology only to minor parties involved in the transport system.
Very high	High need for investing in infrastructure. High need for investing in human capital. Changes in technology may impose mutual adaptation of technology to the parties involved in the transport system.

Local impact

The impact of the solution on the quality of local environment was evaluated considering the following:

Very negative	The solution impairs the quality of local environment. The solution is expected to increase the negative impact of the infrastructure on protected biota. The solution is expected to increase emissions of pollutants in air, soil, or water.
Negative	The solution likely has a negative impact on the quality of local environment. The solution likely increases the negative impact of the infrastructure on protected biota. The solution likely increases emissions of pollutants in air, soil or water.
Neutral	The solution may have an impact on the quality of local environment, but no negative impacts are to be ascribed to the solution.
Positive	The solution likely has a positive impact on the quality of local environment. The solution likely reduces the impact of the infrastructure on protected biota. The solution likely reduces emissions of pollutants in air, soil, or water.
Very positive	The solution restores the quality of local environment. The solution is expected to minimize the impact of the infrastructure on protected biota. The solution is expected to minimize emissions of pollutants in air, soil, or water.

Global impact

The impact of the solution on the quality of global environment (the greenhouse effect) was evaluated considering the following:

Very negative	The implementation of the solution impairs the environment at the global level. For example, the solution directly increases the carbon footprint of the infrastructure.
Negative	The implementation of the solution likely contributes to the impairment of the environment at the global level. For example, the solution likely contributes to increase the carbon footprint of the infrastructure.
Neutral	The implementation of the solution is not expected to have a positive or negative impact on the quality of the environment at the global level. No changes in the carbon footprint of the infrastructure are expected due to the implementation of the solution.
Positive	The implementation of the solution likely contributes to improve the environment at the global level. For example, the solution likely contributes to decrease the carbon footprint of the infrastructure.
Very positive	The implementation of the solution directly contributes to improve the environment at the global level. For example, the solution minimizes the carbon footprint of the infrastructure.

Solutions to improve the environmental performance of airports

General SWOT analysis of airport infrastructures

Airport infrastructures

- Pula Airport
- Dubrovnik Airport
- Aeroporti di Puglia
- Rimini Airport
- Pescara Airport

Shared Strengths	Shared Weaknesses
Small to medium airports; A small number of competitive airports for the region; General upward trend of air traffic; Airports serving mainly air passenger transport; Large volume of receptive tourism; Possible "external" gross domestic product growth.	Small to medium airports; Contribution to the environmental pollution of the area; Conflicts between airport operations and existing land uses; Seasonal airports experiencing seasonal concentrations; Dependence on "external" gross domestic product growth.
Shared Opportunities	**Shared Threats**
Proximity of airport infrastructure to urban centre and areas of natural and cultural heritage; Airports serving touristic areas; Connection between the infrastructures of different transport networks; Potential receptive tourism (cooperation with tour operators) outside the "main" season; Development of non-aviation activities (hotel, offices, advertising, car parking, etc.); Attracting new airlines (airline marketing); Participation in international projects; Availability of EU financial instruments for support of environmental protection.	Proximity of airport infrastructure to urban centre and areas of natural and cultural heritage; Airports serving touristic areas; Planning and development by municipality of areas affected by the presence of airport operations; Ownership of surrounding land; Poor development in the tourism sector will reduce the window of opportunity for airport development; Danger of continued instability of the main target markets; Low environmental consciousness and resisting bad practices.

Continuous descent approach, (continuous descent operations)

Main objectives

Noise reduction, reduction in fuel consumption, and thus reduction in airborne pollutant emissions and carbon footprint.

Case studies

Groningen Airport Eelde, Netherlands [1].

Solution

This is an aircraft operating technique in which an arriving aircraft descends from an optimal position, with minimum thrust and without level-off. This technique allows for a smooth, constant angle of descent towards the landing strip. To implement the continuous descent approach, cooperation is needed between pilots, controllers, airline company managers and airport operations managers.
Stakeholders involved in the designing and implementation of the solution: the national air traffic control providers - Air Traffic Control the Netherlands LVNL, Eurocontrol, and airlines.

Solution improvement on

Weaknesses	Improvement
Contribution to the environmental pollution of the area	Medium
Conflicts between airport operations and existing land uses	Very high
Small to medium airports	-
Seasonal airports experiencing seasonal concentrations.	-

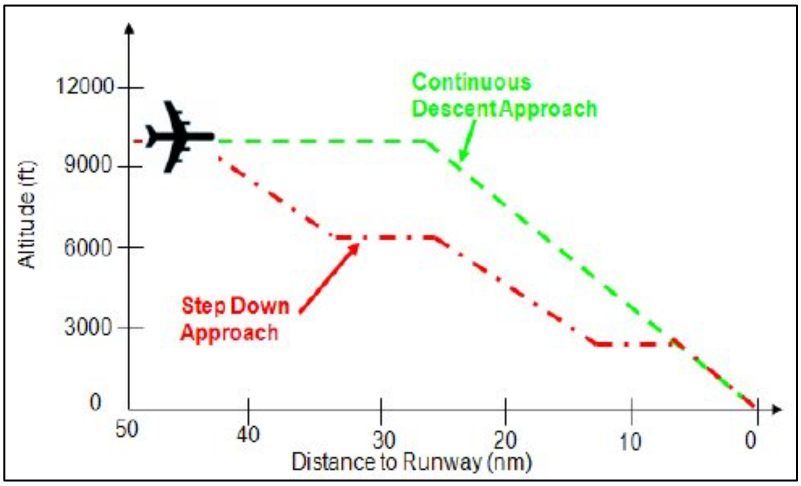


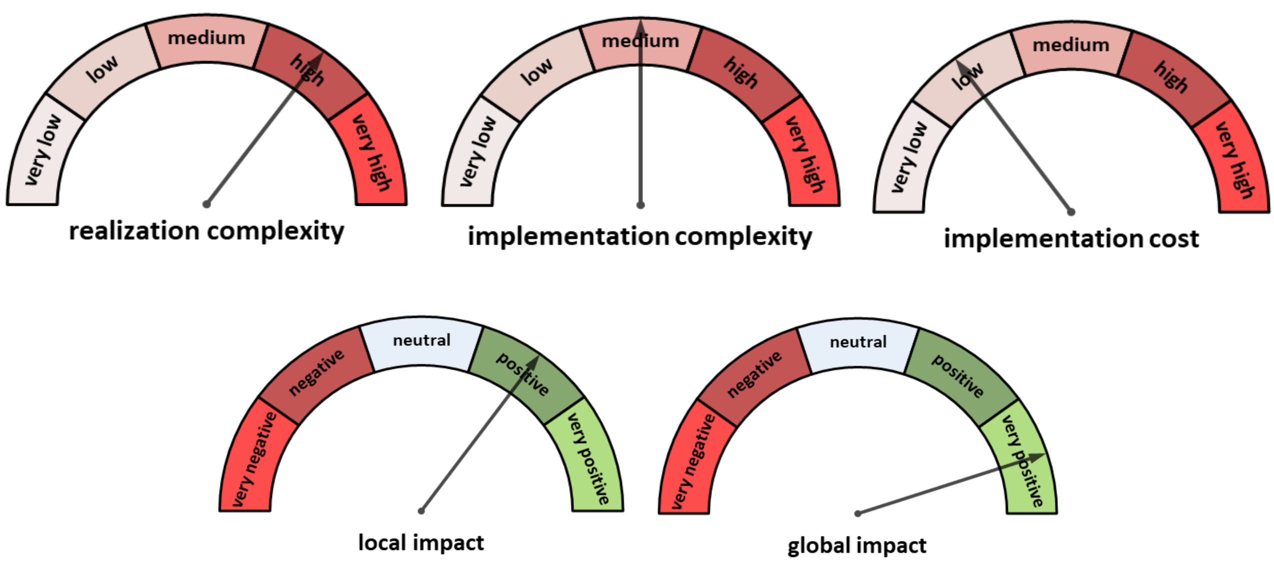
Figure 1. Continuous descent approach versus step descent approach[2].

[1] http://archive.northsearegion.eu/files/repository/20141216172208_ROMN13102402-GSAmag-LR.pdf
[2] Alamet et al. 2010. A dynamic continuous descent approach methodology for low noise and emission. In *29th Digital Avionics Systems Conference* (pp. 1-E). IEEE. DOI: 10.1109/DASC.2010.5655502

SWOT strategies

Converting W into S	Applying this procedure, airlines may save time and fuel.
Converting S into W	To space and separate aircrafts applying this procedure may limit airport capacity.
Converting T into O	Better relationship between airport and residents because of reduced noise nuisance.
Converting O into T	Defining new flight procedures depends on the national aviation authority with the possibility of flight procedures not optimized with respect to environmental issues because of security standards.
Matching O to S	High attractiveness of the airport because the airlines applying this procedure would benefit for fuel consumption savings.
Avoid T and W	Redesigning airport arrival and departure routes may be subject to environmental constraints. The possibility of defining new flight procedures depends on the national aviation authority.

Solution indicators



Airport collaborative decision making

Main objectives

Noise nuisance reduction, reduction in fuel consumption, and thus reduction in airborne pollutant emissions and carbon footprint.

Case studies

More than 20 airports across Europe (e.g., London Gatwick, Venezia, Paris Charles de Gaulle, etc.).

Solution

Airport-collaborative decision-making aims at improving the predictability of air traffic and the overall efficiency of airport operations. Through information sharing and procedural adherence across the involved stakeholders (e.g., technical enablers, procedural enablers) improvements are achieved in arrival, off-block, and take-off predictability. Milestones are set across the aircraft inbound, turn round, and outbound sequencing processes.
Project team and partners for designing and implementing this solution at Milan Malpensa: SEA Spa Milan Airports, Italian Civil Aviation Authority – ENAC, Italy's Air Navigation Service Provider – ENAV, EUROCONTROL, aircraft operators, ground handlers, airport operators, air traffic control, and network management operations centre[3].

Solution improvement on

Weaknesses	Improvement
Contribution to the environmental pollution of the area	Very high
Conflicts between airport operations and existing land uses	-
Small to medium airports	Medium
Seasonal airports experiencing seasonal concentrations	High

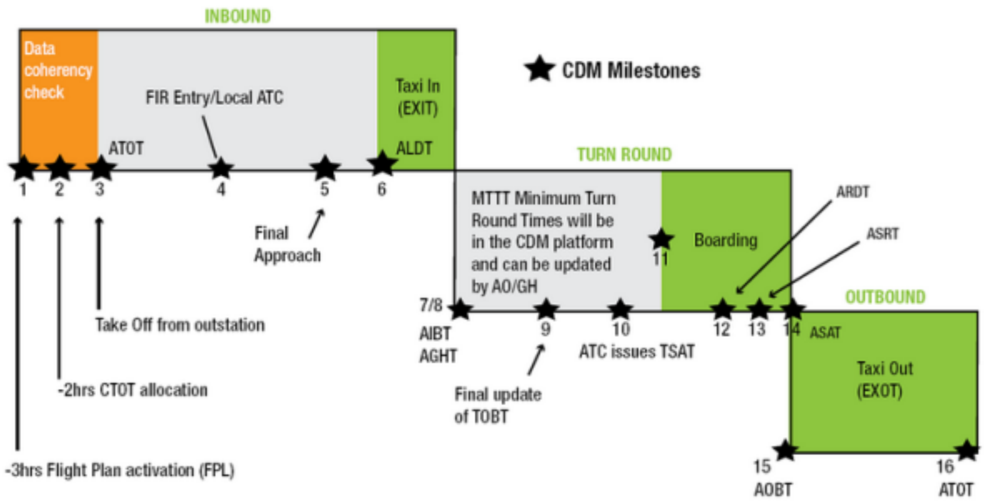


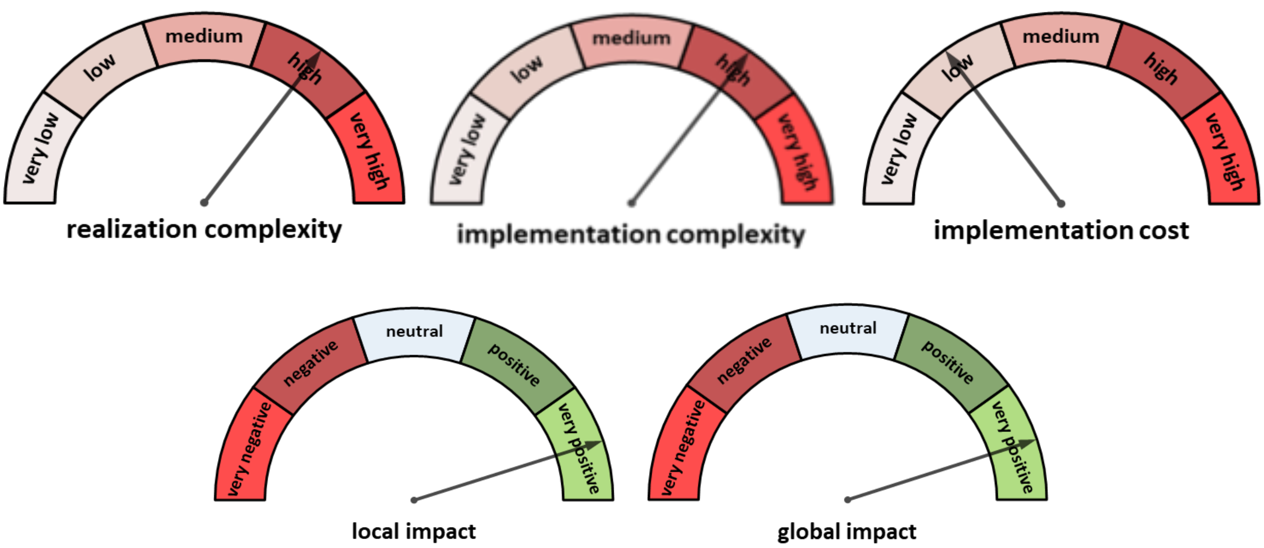
Figure 2. Airport collaborative decision making procedure at Milano Malpensa Airport[3].

[3] https://www.milanomalpensa-airport.com/en/airport-regulations/a-cdm-procedures

SWOT strategies

Converting W into S	Increased punctuality. Better planning and management of gates and stands. Maximum capacity utilization. Better adherence to schedule and slots. Reduced taxi-out time. Optimized use of airspace capacity. Cost-effective solution for the airlines.
Converting S into W	The space configuration of terminal area route may cause flight conflicts.
Converting T into O	Lower operating costs due to reduction of fuel consumption related to flight operations.
Converting O into T	Conflicting air navigation requirements (e.g. safety, environment, economic, capacity) hinder full potential of operational initiatives.
Matching O to S	Improved operations result in high level of passenger satisfaction.
Avoid T and W	Structural limits of the airport infrastructure make the airport not fit for growing demand from commercial air transport.

Solution indicators



Noise mitigation measures

Main objectives

To provide information about simple noise reduction measures to residents who wish to reduce aircraft noise intrusion into their homes.

Case studies

Perth Airport, Australia.

Solution

To provide information to existing home owners who wish to reduce aircraft noise intrusion into their homes thorough simple noise reduction measures. Example of passive noise protection in existing houses follows[4]:

Solution	Comment
Seal gaps	Seal gaps around window frames and doors, using silicone sealant. Available from hardware stores.
Add seals to doors/ upgrade door type	Compressible seals to frame and drop seal to threshold. Available from hardware stores or other suppliers.
Seal eaves	Seal eaves using timber or compressed fiber cement sheeting.
Replace hollow doors	Replace any existing hollow core external doors with solid core door with acoustic seals. Requires specialist suppliers.
Add seals to windows	Install compressible seals.
Upgrade glazing windows	Replace the glazing glass with thicker (10 mm) laminated ones. Only recommended for few rooms (bedrooms) due to cost.
Treat or remove skylight	Add a layer of 10 mm laminated glass at the bottom of the skylight.
Insulate ceiling	Insulation needs to cover entire ceiling, (acoustic insulation > 50 mm).
Replace windows	Replace window frames with awning or casement types with correct seals and about 10 mm laminated glass. High cost expected.
Double glazing	Separate frames recommended over single units.

[4] Perth Airport. 2016. Reducing Aircraft Noise in Existing Homes ... - Perth Airport

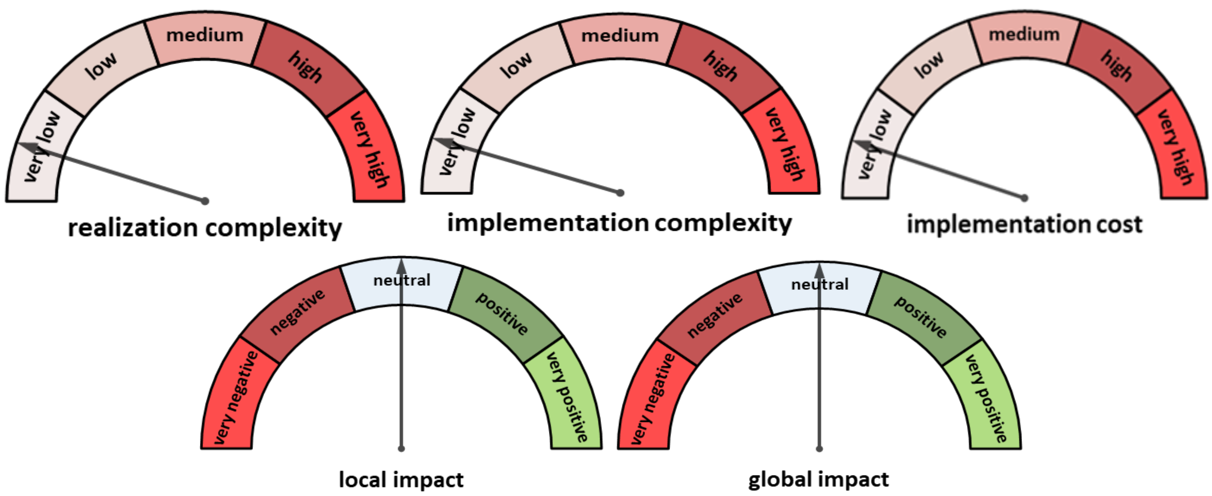
Solution improvement on

Weaknesses	Improvement
Contribution to the environmental pollution of the area	Low
Conflicts between airport operations and existing land uses	High
Small to medium airports	Low
Seasonal airports experiencing seasonal concentrations	-

SWOT strategies

Converting W into S	Reduce the financial burden on the airport neighbour for passive noise protection.
Converting S into W	Depreciation of houses within a given noise exposure area.
Converting T into O	Some of the measures implemented for noise insulation of houses are effective in increasing the thermal insulation too.
Converting O into T	Facilitation of local consultation increases the pressure of local communities and the requests for funding investments.
Matching O to S	Funding investments increase the real estate market valuations.
Avoid T and W	Restriction of airport operations and airport expansion due to noise nuisance.

Solution indicators



Fixed electrical ground power and pre-conditioned air systems

Main objectives

Savings in fuel, reduction of carbon footprint, NO_x, and other airborne pollutants, and noise emissions.

When the aircraft is on the ground and the main engines are turned off, jet fuel based auxiliary power unit mounted on the aircraft provides power for the electrical systems onboard, air circulation, conditioning systems, for starting main engines and to power pneumatic systems.

Case studies

Nice Côte d'Azur Airport, France; Zurich Airport, Switzerland; Heathrow Airport, United Kingdom; Barcelona El Prat Airport and other 11 airports in Spain.

Solution

To reduce the CO2 and airborne pollutant emissions produced by aircraft ground operations, the electrical and air conditioning loads can be supplied at the stand by ground based systems with higher efficiency.

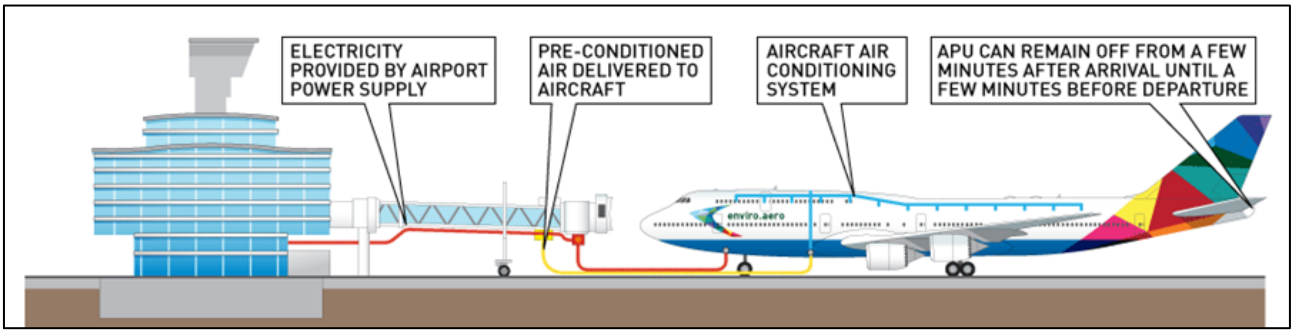


Figure 3. Electrical supply system and pre-conditioned air system scheme[5].

Case studies

Stansted Airport, United Kingdom[6].

Solution

Supply of fixed electrical ground power: this system converts grid electricity to power suitable for supplying (3 phase 400Hz) the aircraft through an electrical cable plugged into the underside of the aircraft.

[5] https://aviationbenefits.org/case-studies/fixed-electrical-ground-power/

[6] London Stansted Airport. Fixed electrical ground power. https://live-webadmin-media.s3.amazonaws.com/media/3212/nap-fixed-electrical-ground-power.pdf

Case studies

Munich Airport, Germany[7]; Nice Côte d'Azur Airport, France[8].

Solution

Pre-conditioned air system: ground supply of cooled/heated air to the cabin air-conditioning system. Air is provided by the central energy plant of the airport or through decentralised, gate mounted chiller/heater units on or near each airbridge.

Figure 4. Pre-conditioned air system at Munich Airport[7].

Case studies

Douala International Airport, Cameroon[9].

Solution

The solar-to-gate project uses solar energy to power aircrafts at the gate, substituting the use of the auxiliary power unit. A 1.2 MW solar installation is projected to generate 5.5 million kWh per year eliminating more than 2 000 tonnes of CO_2 from more than 5,000 flights annually.
This initiative was implemented by the International Civil Aviation Organization (ICAO) with funding support from the European Union and the active collaboration of the Government of Cameroon.

[7] https://www.munich-airport.com/a-fresh-breeze-thanks-to-pca-1229006
8 https://aviationbenefits.org/media/100169/aviation-climate-solutions_web-82.pdf
9 https://www.icao.int/Newsroom/Pages/ICAO-launches-1.2MW-solar-at-gate-pilot-project-in-Cameroon-to-reduce-aircraft-CO2-emissions-during-ground-operations.aspx

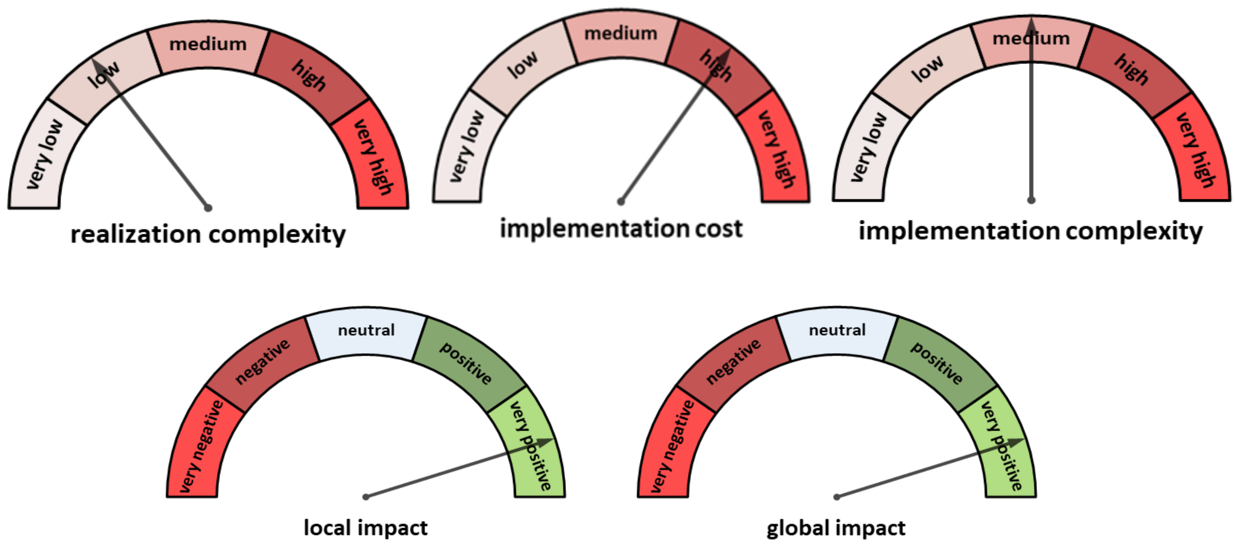
Solution improvement on

Weaknesses	Improvement
Contribution to the environmental pollution of the area.	Very high
Conflicts between airport operations and existing land uses	High
Small to medium airports	Medium
Seasonal airports experiencing seasonal concentrations	None

SWOT strategies

Converting W into S	Lower cost per kWh makes this option profitable for airlines and potential revenues for the airport.
Converting S into W	The technological innovation in the aviation sector may request frequent technological updating of ground based systems.
Converting T into O	The use of auxiliary power units may be subject to certain restrictions imposed by the airport.
Converting O into T	Possible reforms in safety and environment regulations could bring in stricter compliance norms about airborne pollutant emissions and noise emission from aircraft on terminal stands.
Matching O to S	Reduction in noise emission and airborne pollutant emissions at the apron increase customer satisfaction of the airport.
Avoid T and W	The provision of ground services such as fixed electrical ground power and pre-conditioned air systems may make the airport not fit potential fluctuation in the aviation market.

Solution indicators



Deployment of sustainable low-carbon fuels (e.g., bio jetfuels)

Main objectives

Carbon footprint reduction. The aeronautics industry and its energy suppliers shift from fossil fuel to renewable/alternative energies (e.g. biofuels) sustainably produced.

Case studies

Oslo Airport, Norway[10]; Helsinki Airport, Finland.

Solution

Regular flights using blends of conventional fossil-based and bio-based aviation fuel are already being performed from several airports in the EU.
The Copenhagen airport is a founding partner in an initiative involving other relevant parties from the entire supply chain regarding the development of sustainable jet fuels.
Jet biofuel, both imported from an extra EU country and produced in Finland, was successfully offered to all airlines at Oslo Airport. Stakeholder involved: Norwegian state-owned airport operator, academia, potential biofuel producer, aviation division of a multinational oil and gas company, airlines, and other stakeholders.

Solution improvement on

Weaknesses	Improvement
Contribution to the environmental pollution of the area	Low
Conflicts between airport operations and existing land uses	-
Small to medium airports	-
Seasonal airports experiencing seasonal concentrations	-

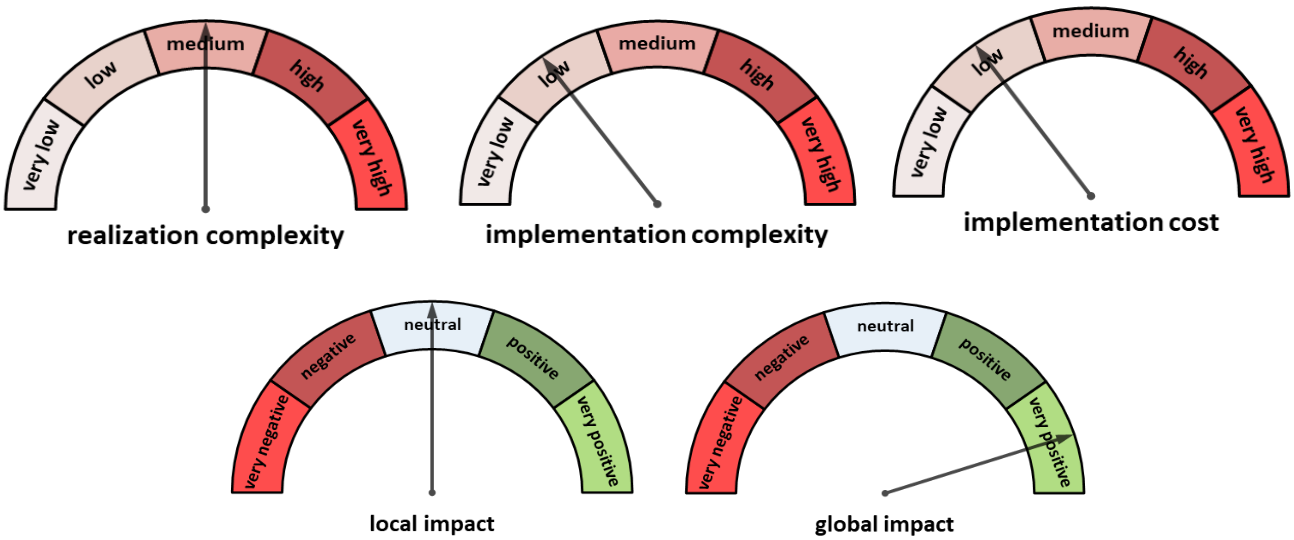
Figure 5. Renewable diesel for refueling planes at Helsinki Airport[11].

[10] https://www.icao.int/Meetings/altfuels17/Documents/Olav%20Mosvold%20Larsen%20-%20Avinor.pdf
[11] https://www.neste.us/aviation/use-renewable-diesel-promotes-helsinki-airports-green-hub-project

SWOT strategies

Converting W into S	Improvement of the aeronautics industry's environmental image. Alleviate the negative impact of oil price fluctuation.
Converting S into W	Regulatory burden hinders the access to biofuel market.
Converting T into O	Helps in achieving credibility and building a green corporate image. The capital-intensive production of biofuel attracts investments and accelerate the implementation of biofuel market. Improvement of the aeronautics industry's environmental image.
Converting O into T	Biofuels not completely sustainable produced threatens biodiversity and food security.
Matching O to S	Emission-saving project accesses to credits from the EU emission trading system and waives domestic CO_2-tax.
Avoid T and W	Instability of energy market. Need for cycle assessment certifying that production of biofuel does not cause adverse environmental impacts or competition with food production, or compromise bio-diversity, etc.

Solution indicators



Electrically powered buses

Main objectives

Minimizing carbon footprint, reduction in airborne pollutant emission, and noise nuisance.

Case studies

Schiphol Airport, Netherlands; Brussels Airport, Belgium.

Solution

Schiphol Airport set a condition of the contract for emission-free bus fleet. About 100 electric passenger buses are serving the airport. By 2021 these buses will be 254. Stakeholders involved: airport management authority, public transport company Connexxion, Transport Region of Amsterdam[12].

Solution improvement on

Weaknesses	Improvement
Contribution to the environmental pollution of the area	Very high
Conflicts between airport operations and existing land uses	-
Small to medium airports	-
Seasonal airports experiencing seasonal concentrations	-

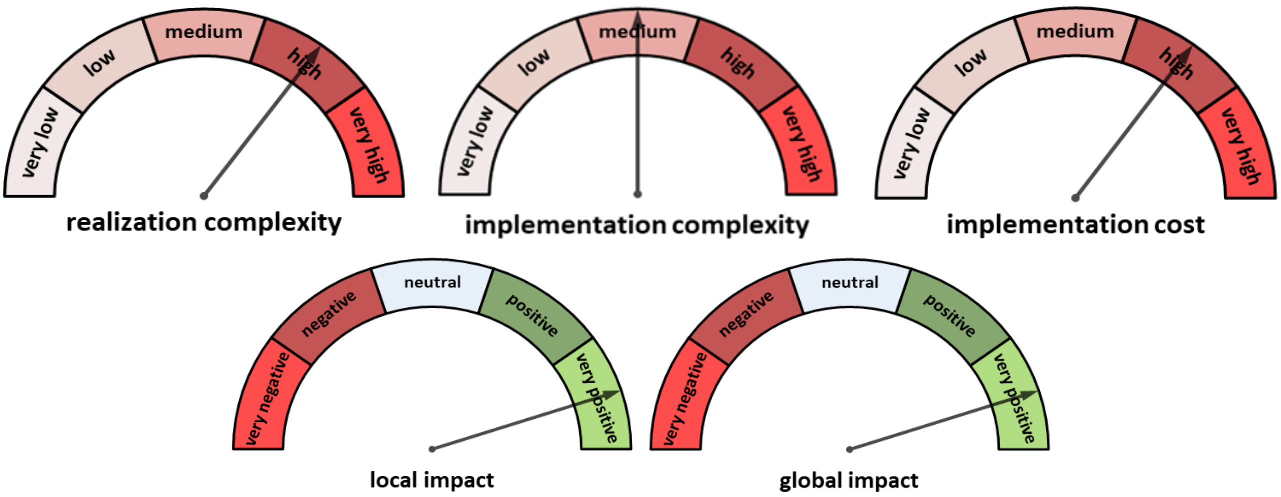
Figure 6. Electric buses at charging station[12].

[12] https://www.schiphol.nl/en/schiphol-group/page/europes-largest-fleet-of-fully-electric-buses/

SWOT strategies

Converting W into S	The substitution of emission-intensive buses with electrically powered ones may be subject to financing and funding opportunities.
Converting S into W	Electric buses are so quiet that artificial noise is needed to prevent accidents.
Converting T into O	Helps in achieving credibility and building a green corporate image. Transport companies may pay reduced electricity tax for the operation of their electric buses.
Converting O into T	Deployment of electric buses does not assure the same level of service.
Matching O to S	Electric buses are perceived positively by passengers and residents thus increase customer satisfaction and public transport attractiveness.
Avoid T and W	The reliability of electrically powered buses strongly depends on the charging infrastructure.

Solution indicators



Charging stations for electric hybrid cars

Main objectives

Minimizing CO_2 emissions, reduction in airborne pollutant emissions and noise.

Case studies

Helsinki Airport, Finland[13].

Solution

To increase use of sustainable e-mobility solutions, charging stations for electric hybrid cars are installed in car parks at the airport. The charging stations are equipped with moderate and slow chargers (charging time from 8 to 3 hours) because the expected parking time is long.

Solution improvement on

Weaknesses	Improvement
Contribution to the environmental pollution of the area	High
Conflicts between airport operations and existing land uses	-
Small to medium airports	Medium
Seasonal airports experiencing seasonal concentrations	-

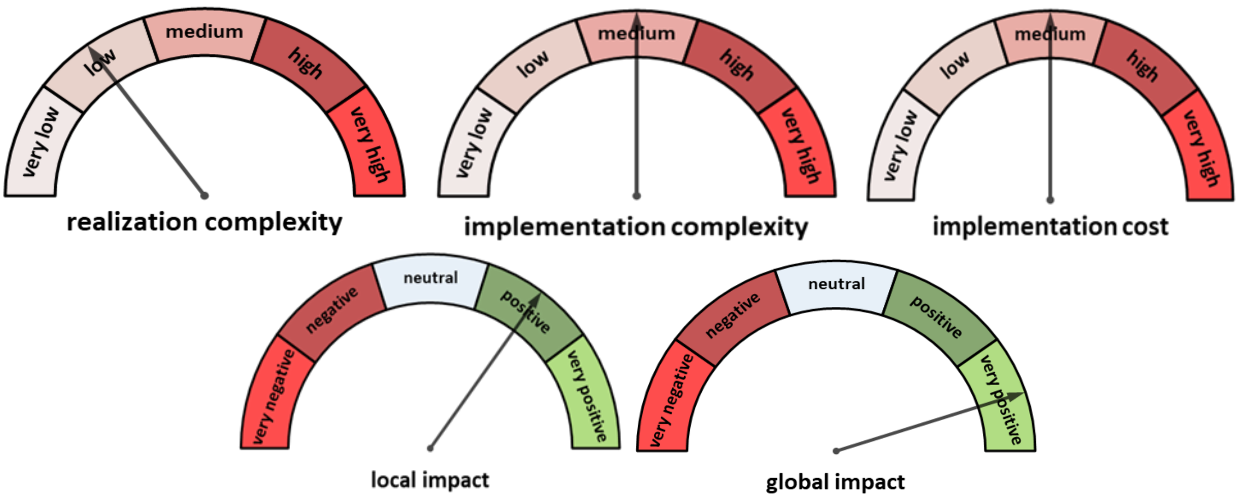
Figure 7. Charging stations for electric cars at Helsinki Airport[13].

[13] https://www.finavia.fi/en/newsroom/2019/good-news-electric-car-drivers-over-60-more-charging-stations-helsinki-airport

SWOT strategies

Converting W into S	Solution for overcoming customers anxiety about finding an available charging station.
Converting S into W	Malfunctions of the chargers worsen customer satisfaction. Increase private car use instead of contributing to the reduction of the use of private cars.
Converting T into O	Increase in airport attractiveness.
Converting O into T	Changes in fuelling process may make the technology obsolete.
Matching O to S	Improved environmental reputation towards the airport infrastructure. Possibility of matching the installation of recharging infrastructure with the generation of renewable energy (solar panels).
Avoid T and W	High infrastructure investment required when there is the need for installing additional infrastructure of power generation and transmission.

Solution indicators



Renewable fuel (diesel from waste and residue) for diesel vehicles

Main objectives

Carbon footprint reduction.

Case studies

Helsinki Airport, and other Lapland Airports such as Rovaniemi, Kuusamo, Ivalo, and Kittilä Airport, Finland[14].

Solution

Finavia-owned diesel vehicles such as apron buses switched to renewable diesel. Renewable diesel is made of waste and residues such as animal fat from food industry and fish processing waste, used cooking oil, technical corn oil and residues from vegetable oil production. This renewable diesel is locally produced, thus with low greenhouse gases emission over the entire life cycle. Furthermore, there is no need for changes for the existing engines[15].

Solution improvement on

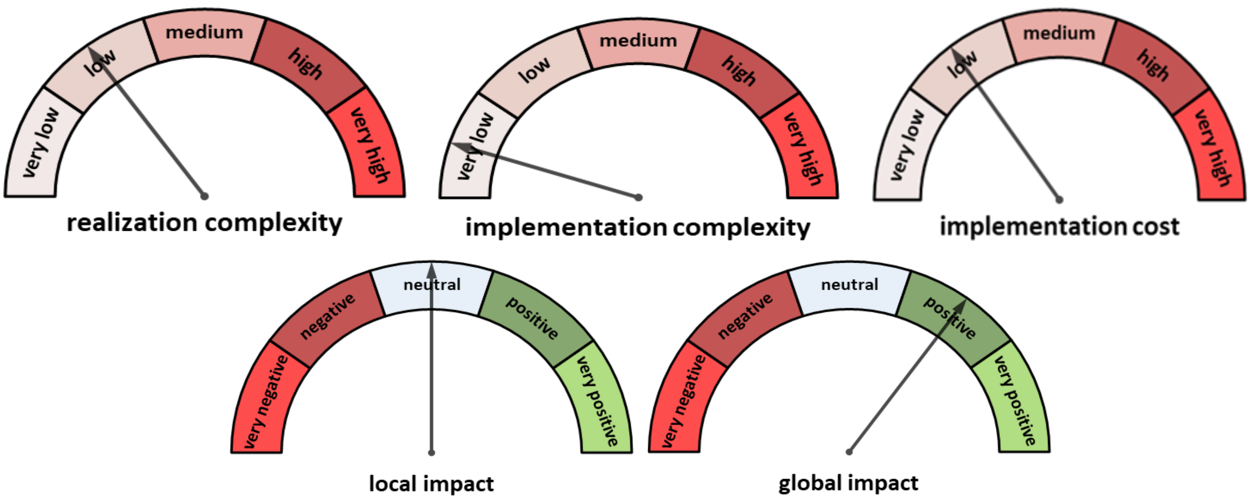
Weaknesses	Improvement
Contribution to the environmental pollution of the area	Low
Conflicts between airport operations and existing land uses	-
Small to medium airports	Low
Seasonal airports experiencing seasonal concentrations	-

[14] https://www.finavia.fi/en/newsroom/2018/finnish-airports-apron-buses-run-on-waste-and-residues
[15] https://www.finavia.fi/en/newsroom/2018/heading-towards-zero-emissions-airports-lapland-airports-finland-switch-neste-my

SWOT strategies

Converting W into S	Locally produced renewable fuel fosters circular economy and contribute to build relationships between the airport management and local community.
Converting S into W	Biofuel production capacity does not satisfy the market needs.
Converting T into O	Increasing the share of renewable fuel in the total fuel consumption related to land side operations at the airport ensure sustainable growth and development.
Converting O into T	Biofuels not completely sustainable produced.
Matching O to S	Renewable fuel is more price stable than fossil fuel.
Avoid T and W	Fluctuations in the local feedstock composition and availability make biofuel production depend on imported feedstock.

Solution indicators



Improvement in energy efficiency/reduction in energy consumption

Main objectives

Reduction in the annual power consumption of the airport infrastructure with savings in power consumption and thus carbon footprint and airborne pollutant emissions reduction.

Case studies

Copenhagen Airport, Denmark; Schiphol Airport, Netherlands.

Solution

Reduction in energy consumption achieved through measures such as[16]:

- Installation of groundwater cooling system with cooling wells;
- Installation of motion-detector-controlled lighting and light-emitting diodes (LEDs) at the airport's carparks. The expected reduction in energy consumption due to smart lighting solutions is up to 70%.

Environmental benefits due to installing LED lamps at Schiphol Airport were[17]:

- Reduced energy consumption (up to 50%);
- Reduced raw material consumption due to longer (75%) life time of the lighting fixtures.

Solution improvement on

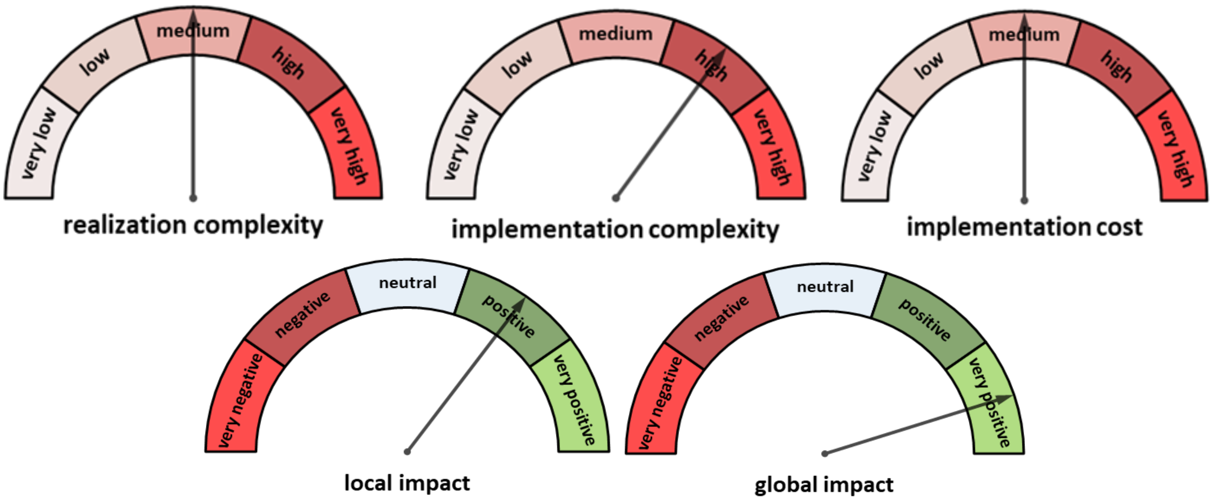
Weaknesses	Improvement
Contribution to the environmental pollution of the area	High
Conflicts between airport operations and existing land uses	-
Small to medium airports	High
Seasonal airports experiencing seasonal concentrations	High

[16] https://cph-prod-cdn.azureedge.net/48cd3d/globalassets/8.-om-cph/6.-investor/arsrapporter/en/cph-and-society-2013.pdf
[17] https://www.icao.int/environmental-protection/Documents/EnvironmentalReports/2019/ENVReport2019_pg275-278.pdf

SWOT strategies

Converting W into S	Energy savings reduce the infrastructure management costs. Reduction of raw material consumption and waste because of the long lifetime of LED lamps.
Converting S into W	Lack of funds.
Converting T into O	Measures aiming at improving energy efficiency and reducing energy consumption protect against fluctuating energy prices and changes in economic conditions. Reduced electricity demand increase reliability in case of events of stress on electric system.
Converting O into T	Long term investments may be not attractive for short term management.
Matching O to S	Reduction of the infrastructure management costs ensures competitiveness and revenues.
Avoid T and W	Need for additional funds to comply with more stringent requirement in the future.

Solution indicators



Water-smart strategies aiming at preserving freshwater

Main objectives

To reduce the water footprint of the airport infrastructure.

Case studies

Boston Logan International Airport[18],United States of America; Delhi Airport[19], India.

Solution

Solutions aiming at reducing the water footprint of the airport infrastructure includes:
To save freshwater by reducing water usage and reusing as much water as possible:
- Low-flow bathroom fixtures, low flush water closets and cisterns;
- Rainwater harvesting;
- Treated wastewater for landscaping, toilet flushing, and in make-up air system for heating ventilation and air conditioning system.

To improve groundwater recharge:
- Rainwater harvesting wells in the storm water drains.

Solution improvement on

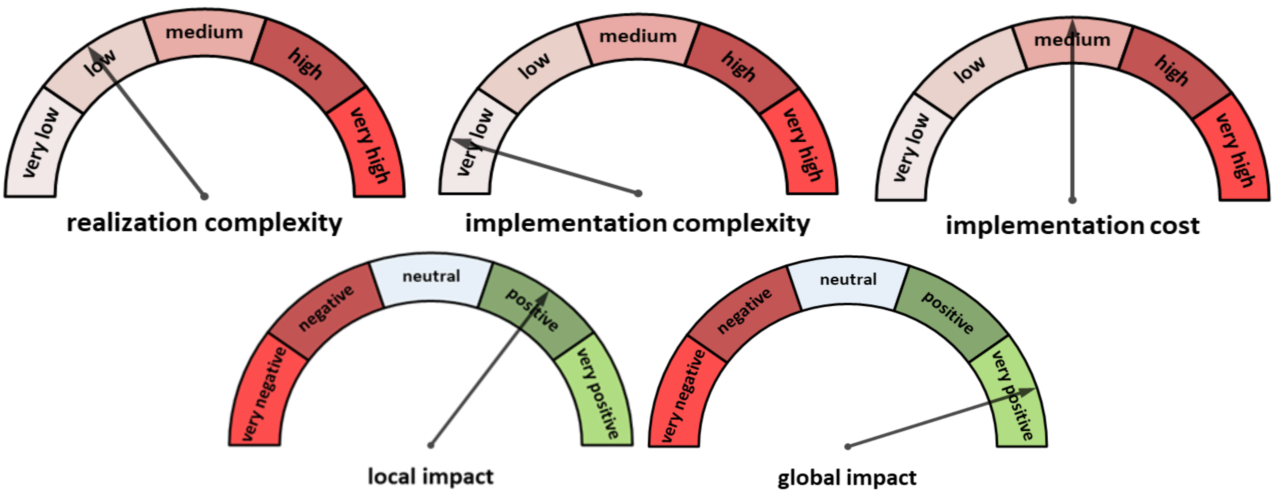
Weaknesses	Improvement
Contribution to the environmental pollution of the area	High
Conflicts between airport operations and existing land uses	Low
Small to medium airports	High
Seasonal airports experiencing seasonal concentrations	Very high

[18] https://www.massport.com/media/2774/massport-annual-sustainability-and-resiliency-report-2018_lr.pdf
[19] https://www.newdelhiairport.in/corporate/our-company/environment

SWOT strategies

Converting W into S	Water savings reduces the infrastructure management costs. Water savings may be achieved in combination with recovery of energy and/or substances.
Converting S into W	Risk of surface and ground water contamination.
Converting T into O	Adoption of smart solutions regarding water scarcity and droughts increase climate resilience.
Converting O into T	More stringent water use efficiency measures and stricter efficiency standard request significant investments.
Matching O to S	Reduction of the infrastructure management costs ensures competitiveness and revenues.
Avoid T and W	Water scarcity and spikes in water demand due to high number of tourists increase competition for water use between airport infrastructure and other sectors.

Solution indicators



Waste management aiming at zero waste to landfill

Main objectives

The waste produced or brought to the airport site is diverted from landfills through waste management initiatives in line with the waste hierarchy fostering waste prevention, reduction, recycling, and recovery[20].

Case studies

London Stansted airport, United Kingdom.

Solution

Key waste management initiatives include[21]:

- Airport management involves customers and contractors to implement good waste management practices;
- Clear instructions on waste disposal provided to the business partners;
- Incorporate waste management into the Airport training and communication plans;
- Deliver Airport-wide waste awareness campaigns or events;
- Incorporate incentives into cleaning and waste contracts;
- Identify the main waste producers on-airport and develop plans to work in partnership with them;
- Publication of a best practice guide which encourages recycling on board aircrafts;
- Consult and share information with local authorities to ensure the Airport Waste Strategy complies with their objectives.

Actions on waste prevention:

- Develop a framework for incorporating resource efficiency and waste minimization considerations into procurement and supply chain decisions;
- Review packaging waste generated by retailers and passengers to identify waste reduction opportunities;
- Review resource use and waste generated to identify and implement opportunities for waste reduction and for using recycled products.

Actions on waste reuse:

- Use construction waste and amend construction standards to reflect best practice in material reuse;
- Review reuse opportunities across the Airport;
- Revise the building refurbishment guidance to include onsite and offsite reuse opportunities for furniture, electrical equipment and other items;

Actions on waste recovery:

- Implement a collection service for food waste generated by catering outlets in the terminal;
- Encourage increased use of existing recycling collection services through communication, training and appropriate incentives;
- Set recycling targets for the cleaning and waste contractors;
- Regularly review local recycling waste treatment infrastructure and the collection services to ensure new recycling and recovery opportunities are identified.

[20] International Civil Aviation Organization (ICAO). Waste management at airport. Eco airport toolkit. https://www.icao.int/environmental-protection/Documents/Waste_Management_at_Airports_booklet.pdf
[21] https://live-webadmin-media.s3.amazonaws.com/media/3414/waste-strategy-stansted.pdf

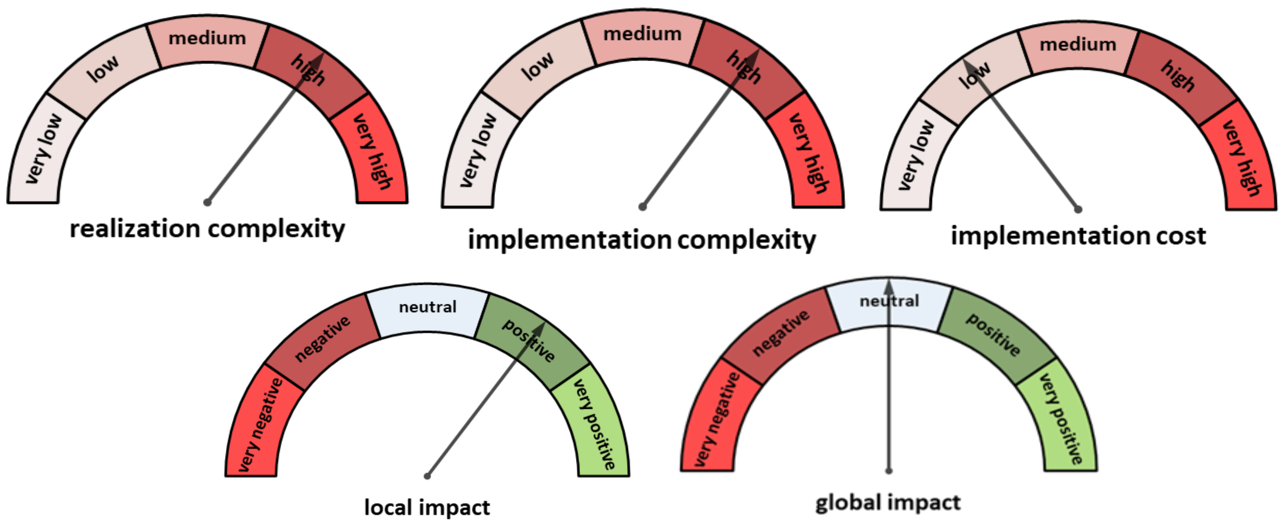
Solution improvement on

Weaknesses	Improvement
Contribution to the environmental pollution of the area	High
Conflicts between airport operations and existing land uses	-
Small to medium airports	High
Seasonal airports experiencing seasonal concentrations	Medium

SWOT strategies

Converting W into S	Efficient waste collection reduces operating costs. Possible revenues deriving from the use of parts of the waste stream as feedstock for renewable energy.
Converting S into W	Ineffective waste management increases operating costs in the short-term.
Converting T into O	This solution helps to enhance green image of the managing authority.
Converting O into T	Lack of proper waste management system in place may cause contamination of airport sites and attract wildlife with negative impact on the safety of operations.
Matching O to S	Waste management strategies in line with the waste management hierarchy provide opportunities such as providing a better outreach to the communities and positively influencing social related activities in the region.
Avoid T and W	Lack of staff involvement and support to the best waste management practices.

Solution indicators



Use of environmentally friendly asphalt (warm-mix asphalt) for repaving runways

Main objectives

Reduction of carbon footprint and airborne pollutants (sulphur dioxide, volatile organic compounds, carbon monoxide, dust, and NOx) emissions at the plant and the paving site, savings of fuel and energy.

Case studies

European airports such as Hamburg, Frankfurt, and Munich Airports in Germany; Cambridge Airport, United Kingdom; Logan International Airport[22], United States of America.

Solution

For repaving the airport's runways, environmentally friendly asphalt can be used.
Warm-mix' asphalt is produced at significantly lower temperature (up to 55 °C lower) than hot-mix asphalt. Furthermore, part of the new asphalt is made from recycled asphalt[23].
Other environmental and health advantages of warm mix asphalt for airports[24]:

- Possibility of reusing binder and stone because of compatibility with reclaimed asphalt pavement;
- Better work environment for the crews installing the new pavement because of reduced worker exposure to fumes.

Solution improvement on

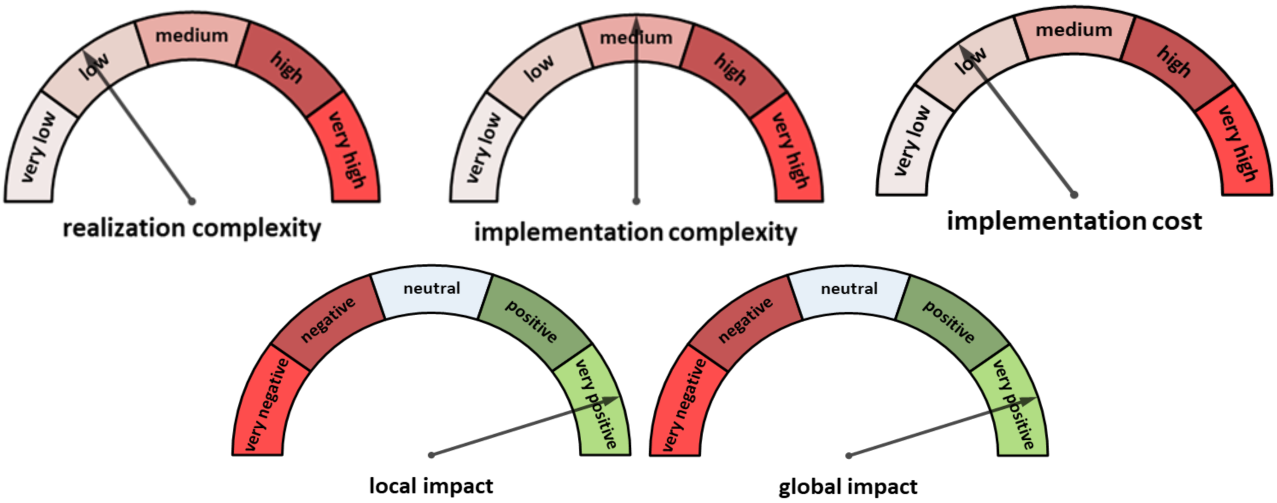
Weaknesses	Improvement
Contribution to the environmental pollution of the area	High
Conflicts between airport operations and existing land uses	-
Small to medium airports	High
Seasonal airports experiencing seasonal concentrations	-

[22] https://csengineermag.com/boston-airport-tests-warm-mix-asphalt/
[23] https://international.fhwa.dot.gov/pubs/pl08007/pl08007.pdf
[24] http://www.aapaq.org/docs/FPC2013/D1S6-01P-White--Warm-mix-asphalt-for-airports.pdf

SWOT strategies

Converting W into S	Increased sustainability of repaving projects.
Converting S into W	Long term performance affects environmental benefits.
Converting T into O	Reduced impact on the surrounding area of the pavement construction operation.
Converting O into T	Environmentally friendly asphalt may be done at expense of life pavements.
Matching O to S	Warm mix asphalt with recycled asphalt minimizes waste, reduces fuel consumption, and realizes cost-savings.
Avoid T and W	Long term environmental benefits and energy savings depend on long term performance on a life-cycle basis.

Solution indicators



Anti-idling campaign: idling gets you nowhere!

Objectives

To improve the local working environment on the apron, and reduce airborne pollutant (particles, NOx) emissions, carbon footprint, and noise nuisance.

Case studies

Copenhagen Airport, Denmark.

Solution

Fliers and small boxes of candy were used to spread messages regarding the anti-idling campaign launched at Copenhagen airport. The main message of the campaign was to remind pilots[25]:

- To turn off the engines when their aircraft are parked on the ramp;
- To turn off as many engines as possible when taxiing from the runway to the aircraft stand;
- To reduce auxiliary power unit use.

Solution improvement on

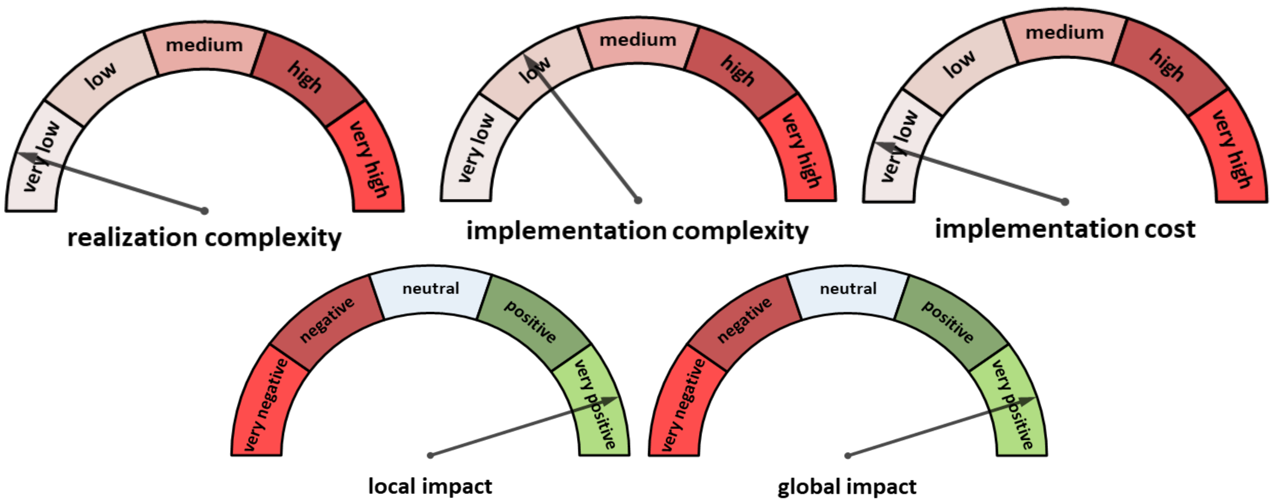
Weaknesses	Improvement
Contribution to the environmental pollution of the area	Very high
Conflicts between airport operations and existing land uses	-
Small to medium airports	Very high
Seasonal airports experiencing seasonal concentrations	-

[25] https://cph-prod-cdn.azureedge.net/48cd3d/globalassets/8.-om-cph/6.-investor/arsrapporter/en/cph-and-society-2013.pdf

SWOT strategies

Converting W into S	Reduction of operating and maintenance costs. It may reduce pressure of local communities on airport operations due to noise nuisance and air pollution.
Converting S into W	The implementation of this solution may be difficult to monitor and subject to the pilots will.
Converting T into O	This solution may be a win-win strategy improving the environmental performances of airport infrastructure and airlines.
Converting O into T	Environmental regulation frameworks impose more stringent requirements.
Matching O to S	It promotes decarbonisation of airports while improving local air quality.
Avoid T and W	Idling for a short time wastes less fuel than turning the engine off and on.

Solution indicators



Intermodal passenger transport (mixed mode commuting)

Intermodality refers to connections between airports and railways, subways, roads, and highways to provide seamless journeys from door to door. Intermodality responds to the general need of travellers to use different modes of transportation in a journey.

Airport with intermodal capabilities

Objectives

Carbon footprint reduction and reduced airborne pollutants emissions because of the reduction of road traffic and congestion.

Case studies

Trieste Airport, Italy.

Solution

An airport with an intermodal transport hub provides air-rail-road modal interchange. This solution aims at discouraging the use of private car providing travellers with fast, environmental-friendly and cost-effective transport solutions.
The airport terminal, the car parks, the bus station, and the railway station are connected by a mid-air pedestrian walkway. A railway station is in a walking distance to Trieste Airport. This railway station is linked to the national railway line. A bus station and a multy-storey car park assure the air-road modal interchange. A daily bus service connects the airport with national and international destinations[26].

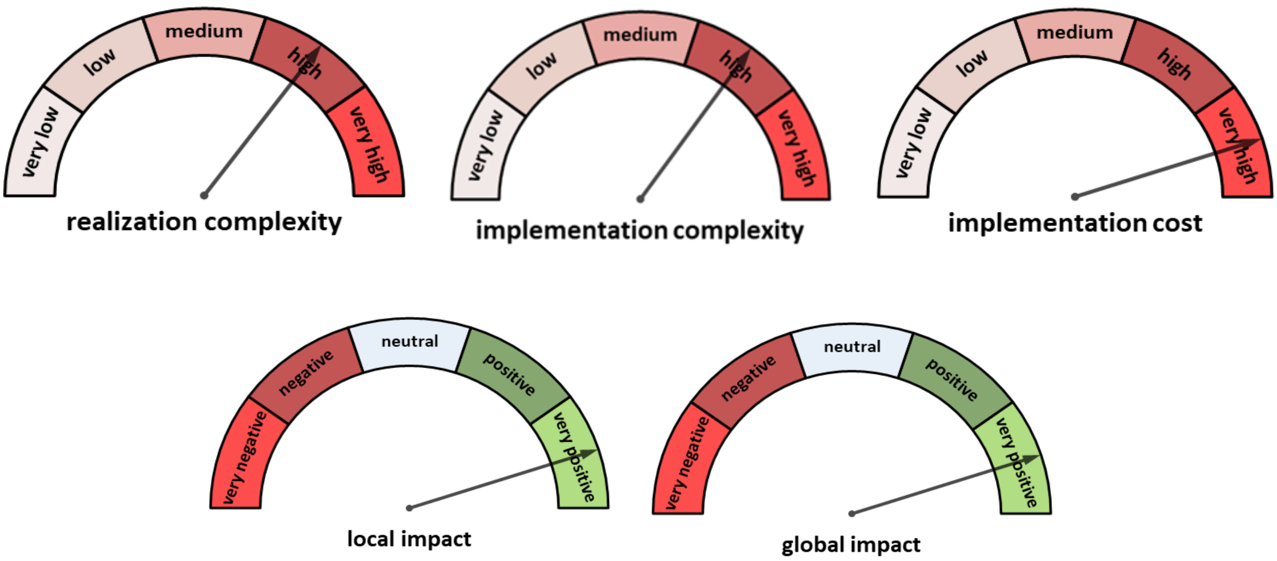
To help the passengers experience take flight at airport intermodal hubs[27]:
- Prior to the trip, to enable travellers to better plan their journey the information are provided regarding transfer to the departure airport and from the arrival airport and the final destination;
- On arrival, passengers are informed about airport-city transfer;
- Visible and clear (visible colours, clear visual language) signage within terminals;
- Proper frequency and early enough/late enough connections to accommodate first/last flight.

Solution improvement on

Weaknesses	Improvement
Contribution to the environmental pollution of the area	Very high
Conflicts between airport operations and existing land uses	-
Small to medium airports	High
Seasonal airports experiencing seasonal concentrations	Very high

[26] https://triesteairport.it/en/airport/polo-intermodale/
[27] http://smart.blog.aeroportodinapoli.it/wp-content/uploads/2016/04/Guidelines-for-Passenger-Services-at-European-Airports-ilovepdf-compressed.pdf

Solution indicators



Air-rail intermodality: from train to plain

Objectives

Carbon footprint reduction, and reduction of airborne pollutant emissions.

Case studies

Vienna Schwechat Airport, Austria.

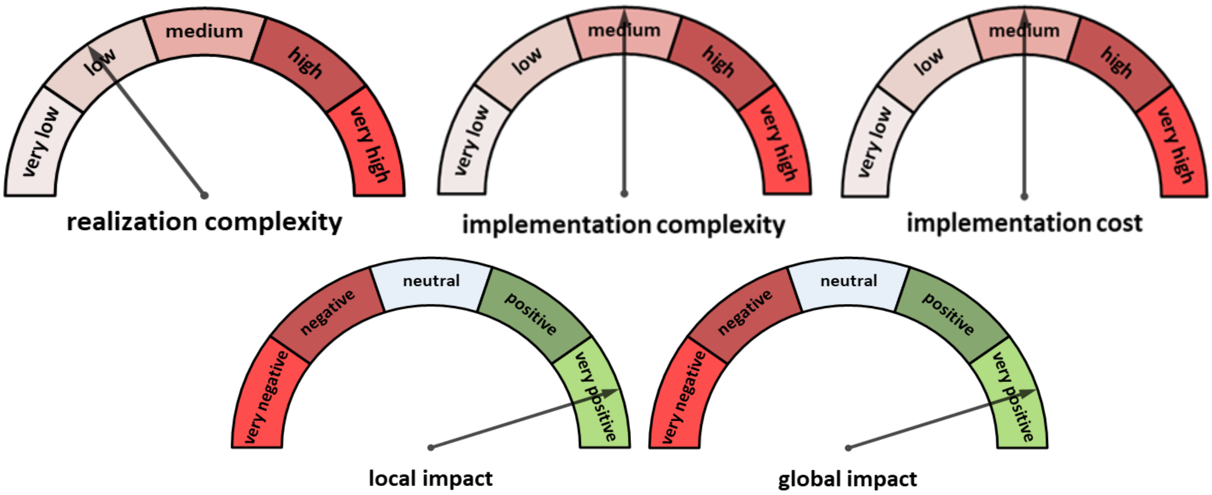
Solution

Passengers can buy a journey by train and plane with a single ticket and have a through trip with guaranteed connections. Combining fares, booking procedures and ticketing provides the passengers a multi modal travel by plane and train.
The whole of Austria is linked with Vienna Schwechat Airport by train, with direct connections daily between Linz Central Station and Vienna Airport, and between Salzburg Central Station and Vienna Airport.
If the train or flight is unexpectedly delayed, an alternative connection is booked for the passengers.
The boarding pass functions as a ticket for the entire journey by rail and air. Furthermore, passengers enjoy a range of benefits.
Stakeholders: rail operator (Austrian Federal Railways); flag carrier (Austrian airline)[28,29].

Solution improvement on

Weaknesses	Improvement
Contribution to the environmental pollution of the area	Very high
Conflicts between airport operations and existing land uses	-
Small to medium airports	-
Seasonal airports experiencing seasonal concentrations	Very high

Solution indicators



[28] https://www.oebb.at/en/tickets-kundenkarten/businessreisen/geschaeftsreisen/zug-und-flug.html
[29] https://www.austrian.com/Info/Book/AIRail.aspx?sc_lang=en&cc=UK

SWOT strategies regarding the solutions about airport with intermodal capabilities and air-rail intermodality.

Converting W into S	It helps address issues such as shortage of capacity at congested airport during seasonal concentrations. Airports with intermodal capabilities have better overall performance compared to their competitor because of increased overall performance and customer satisfaction.
Converting S into W	It may add travel time and inconvenience for passengers who have to change modes.
Converting T into O	A brand name for the air and rail connection helps to promote the service provided and the destination. The catchment area of the airport is expanded with positive impact to the tourist and economic development of the area.
Converting O into T	Intermodal hub infrastructures are capital intensive.
Matching O to S	Effective integration of transport modes helps in increasing attractiveness of the airport. Projects regarding intermodal hubs may attract EU funding*.
Avoid T and W	Intermodality generates additional traffic with the possibility of negative environmental externalities. No easily access to reliable, impartial, and real time information before and during the journey.

*The European Commission supports air transport projects aimed at improving intermodality and airport accessibility along the Europeans corridors that are part of the trans-European transport networks (TEN-T) according to Reg. (EU) no. 1315/2013[30].

[30] Regulation (EU) No 1315/2013 of the European Parliament and of the Council of 11 December 2013 on Union guidelines for the development of the trans-European transport network and repealing Decision No 661/2010/EU Text with EEA relevance. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013R1315

Solutions to improve the environmental performance of ports

SWOT analysis of port infrastructures

Port infrastructures:

- Pula Port
- Dubrovnik Port
- Ancona Port
- Bari Port

Strengths	**Weaknesses**
Plans for future port developments; Destinations of cultural and landscape tourism; Geographical position; Proximity of the port to the city centre; Small to medium ports.	Contribution to the environmental pollution of the area; Mainly seasonal passengers transport; Traffic and infrastructural problems; Conflicts between port operations and existing land uses; Proximity of the port to the city centre; Small to medium ports; Need for new infrastructures to support the transition to sustainable energy sources.
Opportunities	**Threats**
Proximity of the port to the city centre and to areas of natural and cultural heritage; Improving accessibility; Connection between the infrastructures of different transport networks; Availability of EU financial instruments in order to ensure a support to operations management processes aimed at environmental protection in the port; Increased demands on protection of the environment in the area around the ports in order to develop priority sectors for the country; Participation in international projects.	Proximity of the port to the city centre and to areas of natural and cultural heritage; Urban traffic hampering port operations and vice versa; Low environmental consciousness and resisting bad practices; Unresolved environmental and infrastructure issues; Need for large investments for the sustainable development of the port; Lack of communication and coordination between institutions and other stakeholders responsible for implementing environmental legislation; An increase in ship call in the ports is a potential danger to environmental protection.

Onshore power supply for seagoing vessels

Main objectives

Air quality improvement.

Case studies

Port of Gothenburg, Sweden.

Solution

Replacing onboard-generated power from diesel auxiliary engines with electricity generated onshore, a substantial reduction of air pollutants and noise is achieved as well as the reduction of carbon dioxide emissions (depending on the energy source). The standard frequency of 50 hertz for alternating current in Europe is transformed to 60 hertz, which the majority of vessels use as a system frequency. The power is supplied by environmentally labelled electricity such as wind power[31].

Solution improvement on

Weaknesses	Improvement
Contribution to the environmental pollution of the area	High
Small to medium ports	High
Seasonal ports in passengers transport	-
Traffic and infrastructural problems	Low
Conflicts between port operations and existing land uses	High

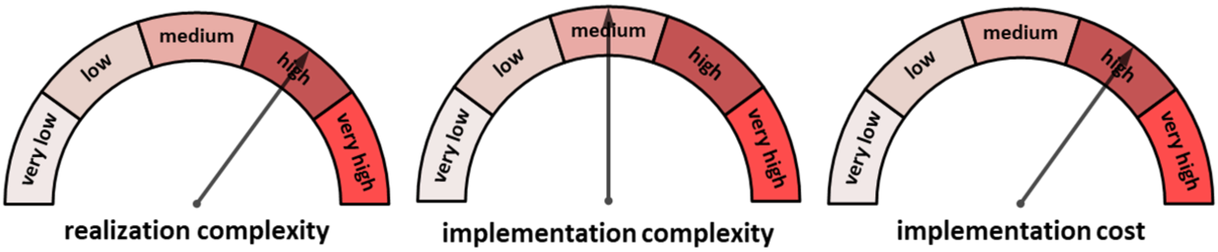
Figure 8. Electricity transfer[32].

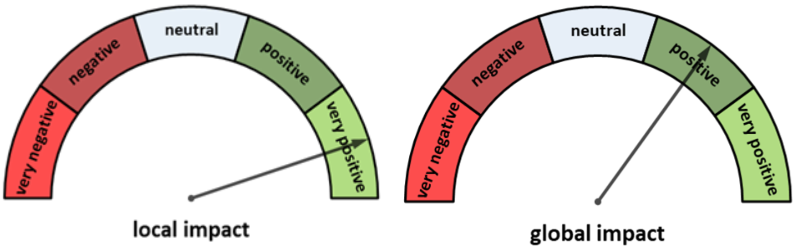
[31] ESPO Green guide; Annex 1: Good practice examples.
[32] www.portofgothenburg.com/about-the-port/greener-transport

SWOT strategies

Converting W into S	Involve local authorities and companies interested in developing the project.
Converting S into W	Not have the support of shipowners.
Converting T into O	Transform the need to improve environmental performance into the ability to collect funds.
Converting O into T	Do not collect funds.
Matching O to S	Collect EU funding. Improve the relations between port and local community.
Avoid T and W	Membership of a few shipping companies and failure to achieve the objectives.

Solution indicators





Redesigning the ferry terminal (buffer zone)

Main objectives

Air quality improvement and traffic management.

Case studies

Port of Dover, England.

Solution

The Port has created a major new and innovative scheme that completely redesigns the entrance to the terminal, forming a buffer zone that provides assembly space removed from the port's internal road network and approach roads for 220 freight vehicles. The project is expected to significantly improve traffic flow and reduce congestion and associated air quality issues along the A20 as well as creating a more efficient operating environment for the customers[33].

Solution improvement on

Weaknesses	Improvement
Contribution to the environmental pollution of the area	Medium
Small to medium ports	High
Seasonal ports in passengers transport	-
Traffic and infrastructural problems	Very High
Conflicts between port operations and existing land uses	Medium

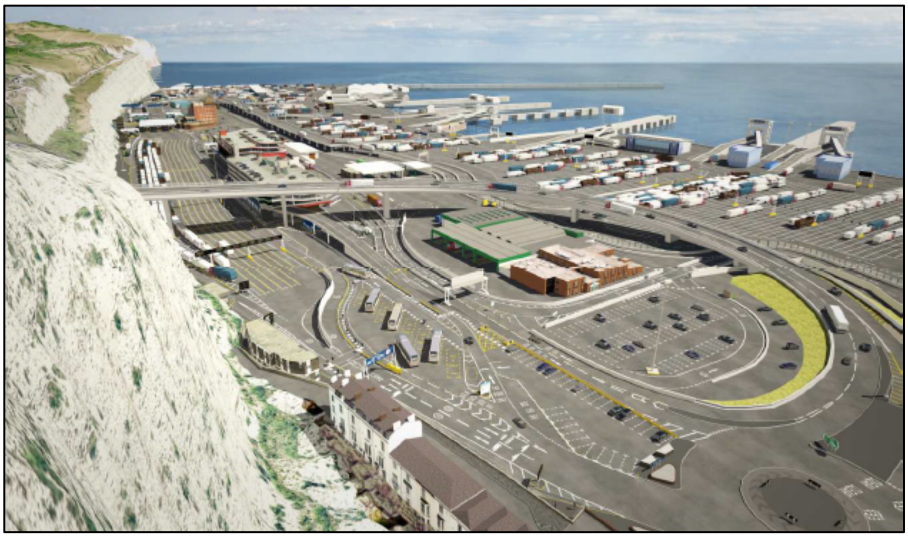


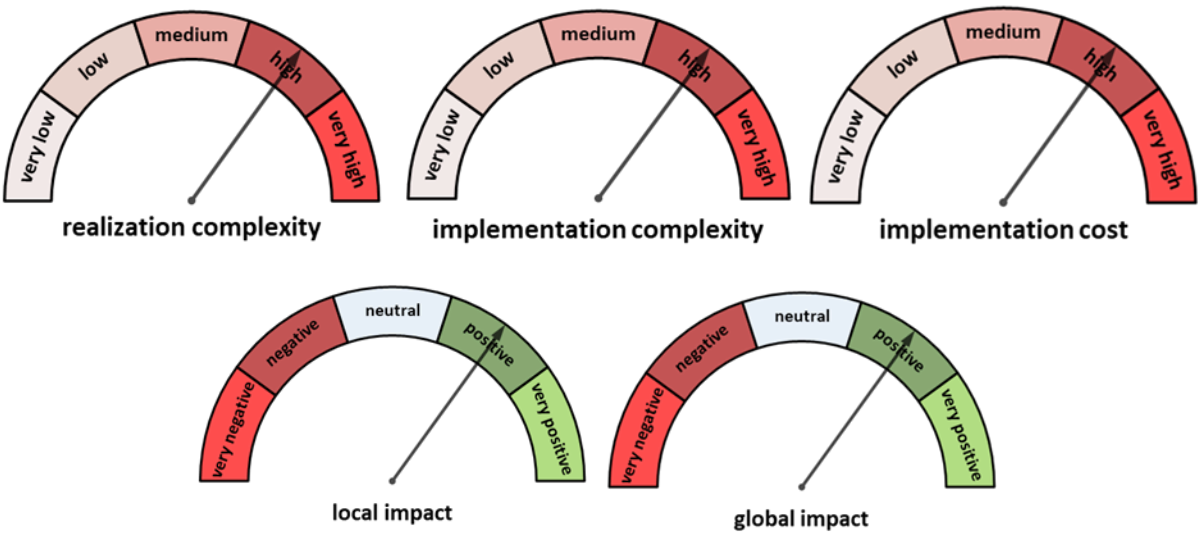
Figure 9. Dover ferry terminal[34].

[33] ESPO Green guide; Annex 1: Good practice examples.
[34] http://www.doverport.co.uk/

SWOT strategies

Converting W into S	Involve all local authorities and inhabitants.
Converting S into W	Landscape impairment.
Converting T into O	Transform the need to improve environmental performance into the ability to collect funds.
Converting O into T	Do not collect funds.
Matching O to S	Collect EU funding.
Avoid T and W	Few funds and delay in construction project.

Solution indicators



Tir trucks under control with the new smart road

Main objectives

Air quality and traffic management.

Case studies

Port of Trieste, Italy.

Solution

A smart road controls the traffic of heavy goods vehicle between the Port of Trieste and the freight terminal, without causing queues and streamlining loading times. The creation of the Smart Road virtual corridor, comprising systems such as smart video cameras for identifying license plates and sensors for the dynamic weighing of vehicles, will make it possible to identify trucks that may have made a detour or stop for the unauthorized loading/offloading of goods by calculating the average time required to travel along the route in question. Additionally, a set of closed-circuit cameras equipped with software will report any queues along the route being monitored and will control traffic to ensure the safety of vehicles on the road. The system can also be used to regulate traffic flows into the Port of Trieste (about 700 vehicles a day)[35 36].

Solution improvement on

Weaknesses	Improvement
Contribution to the environmental pollution of the area	Low
Small to medium ports	Medium
Seasonal ports in passengers transport	-
Traffic and infrastructural problems	Very High
Conflicts between port operations and existing land uses	-

Figure 10. A truck in Port of Trieste[35].

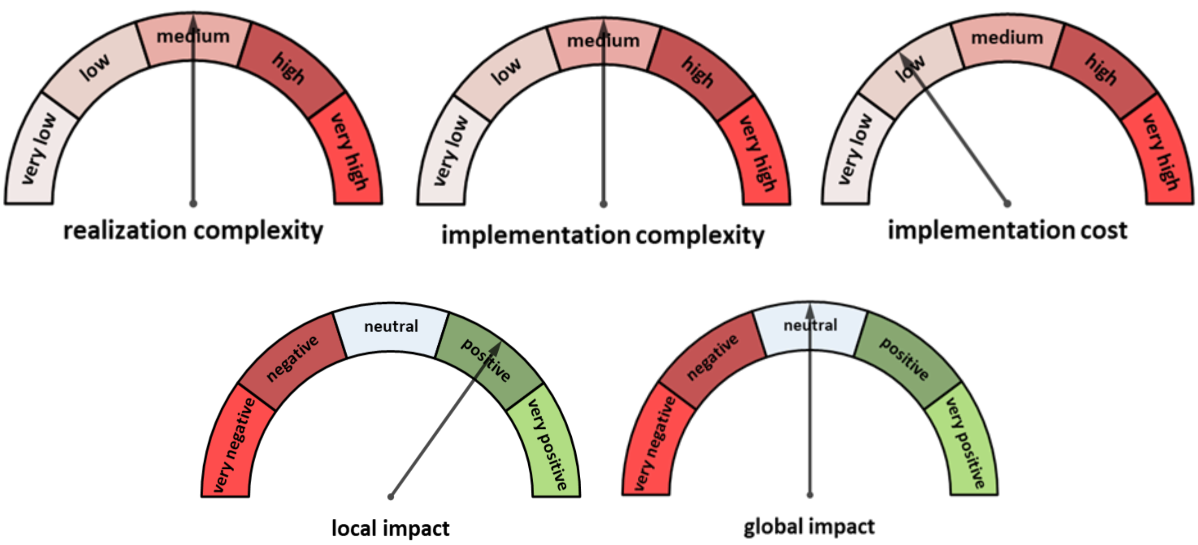
[35] http://www.adriaports.com/en/port-trieste-trucks-under-control-new-smart-road

[36] www.porto.trieste.it/eng/2019-07-11/port-of-trieste-and-anas-tir-trucks-under-control-with-the-new-smart- road.html

SWOT strategies

Converting W into S	Truck drivers are well informed about the operation of the smart road.
Converting S into W	The malfunction of the elements of the smart road system.
Converting T into O	Involve local authorities in the project.
Converting O into T	Do not collect funds.
Matching O to S	Collect EU funding. Reduction of traffic delays and economic benefits for transport companies.
Avoid T and W	Need for checking monitoring system causes work delays.

Solution indicators



Container exchange by rail (PortShuttle)

Main objectives

Air quality and intermodality.

Case studies

Port of Rotterdam, Netherlands.

Solution

PortShuttle Rotterdam was launched to serve the several terminals in Rotterdam in September 2015. The service has since expanded into the neutral rail solution connecting the whole port of Rotterdam. Railway operators, shipping companies and logistics service providers use the PortShuttle to transfer small or large numbers of transhipment containers from one Maasvlakte terminal to another. In principle, thanks to PortShuttle Rotterdam, the containers can be moved from one Maasvlakte terminal to the next within 24 hours[37].

Solution improvement on

Weaknesses	Improvement
Contribution to the environmental pollution of the area	Medium
Small to medium ports	Medium
Seasonal ports in passengers transport	-
Traffic and infrastructural problems	Very High
Conflicts between port operations and existing land uses	High

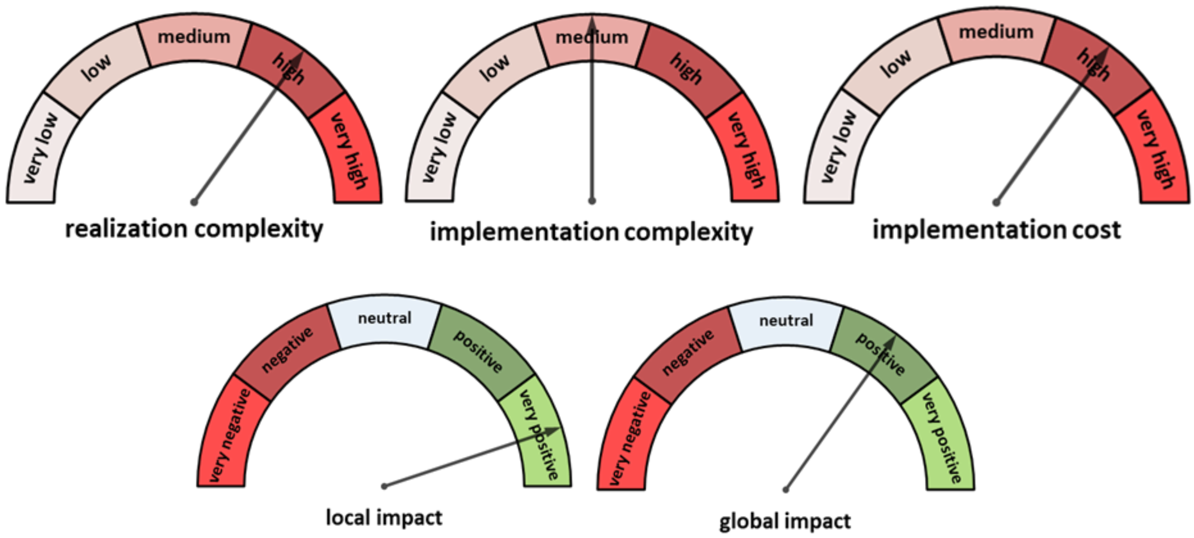
Figure 11. Port shuttle map, Rotterdam[37].

[37] https://portshuttle-rotterdam.com/en/

SWOT strategies

Converting W into S	When all stakeholders have economic benefits.
Converting S into W	Non-synchronization of loading and unloading processes with consequent transport delays.
Converting T into O	Helping all stakeholders to understand business benefits.
Converting O into T	Not raising enough funds to make improvements to the infrastructure.
Matching O to S	Collect EU funding. Make the port capable of increasing its freight traffic.
Avoid T and W	Low participation of railway operators, shipping companies and logistics service providers.

Solution indicators



Venice Offshore Onshore Port System

Main objectives

Air quality and intermodality.

Case studies

Port of Venice, Italy.

Solution

Construction of Offshore Terminal for energy and container. Onshore Container Terminal and transfer vessels. The project consists of:

- Offshore terminal built in the open sea, 8 nautical miles from the coast with 20 m natural depth. The platform will be protected by a 4.2 km outer embankment that includes an energy terminal and a container terminal able to dock up latest generation container ships;
- Onshore terminal integrated with the offshore system, built in an area of 90 ha;
- Semi Submersible Barge Transport, a new means of transport to connect the offshore to the onshore and vice versa[38].

Solution improvement on

Weaknesses	Improvement
Contribution to the environmental pollution of the area	High
Small to medium ports	Very high
Seasonal ports in passengers transport	-
Traffic and infrastructural problems	Very High
Conflicts between port operations and existing land uses	Low

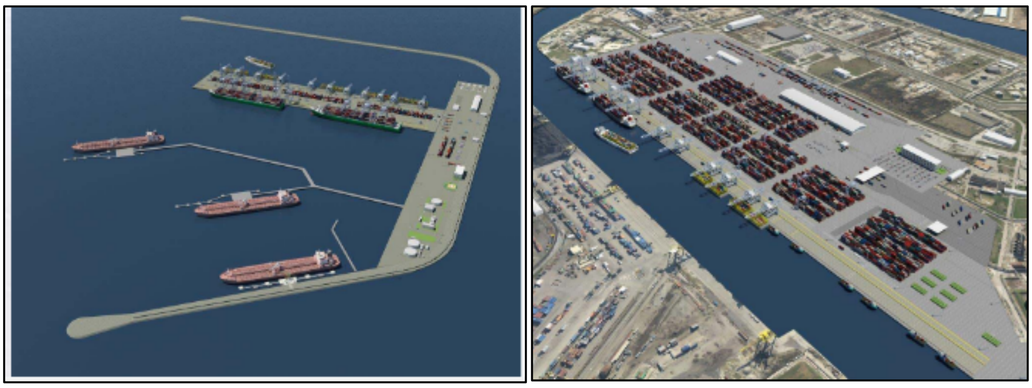


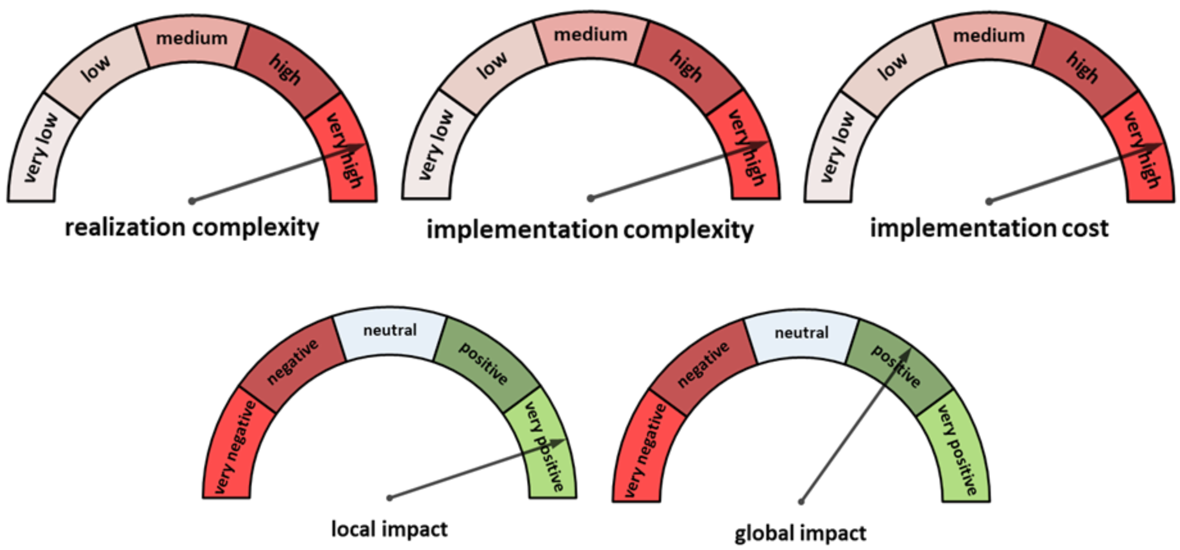
Figure 12. Offshore and onshore terminal[38].

[38] https://ec.europa.eu/eipp/desktop/it/projects/project-19.html

SWOT strategies

Converting W into S	Involve local authorities. Informed the inhabitants of the work benefits.
Converting S into W	Not have support of shipowners.
Converting T into O	Transform the need to improve port commercial performance into the ability to collect funds.
Converting O into T	Not raising enough funds to make infrastructure improvements.
Matching O to S	Collect EU funding. Make the port able to increase its freight traffic.
Avoid T and W	Accelerate construction time. Build in an eco-friendly way.

Solution indicators



Logistics application (OnTrack)

Main objectives

Intermodality.

Case studies:

Port of Rotterdam, Netherlands.

Solution

In a perfect rail chain, all parties would have access to the same accurate real-time information such as capacity, scheduling, and status information. OnTrack provides insight in the expected time of arrival (ETA) and terminal handling of trains by providing a shared view of accurate rail and cargo information across the entire chain[39].

Solution improvement on

Weaknesses	Improvement
Contribution to the environmental pollution of the area	Low
Small to medium ports	Medium
Seasonal ports in passengers transport	-
Traffic and infrastructural problems	Very High
Conflicts between port operations and existing land uses	-

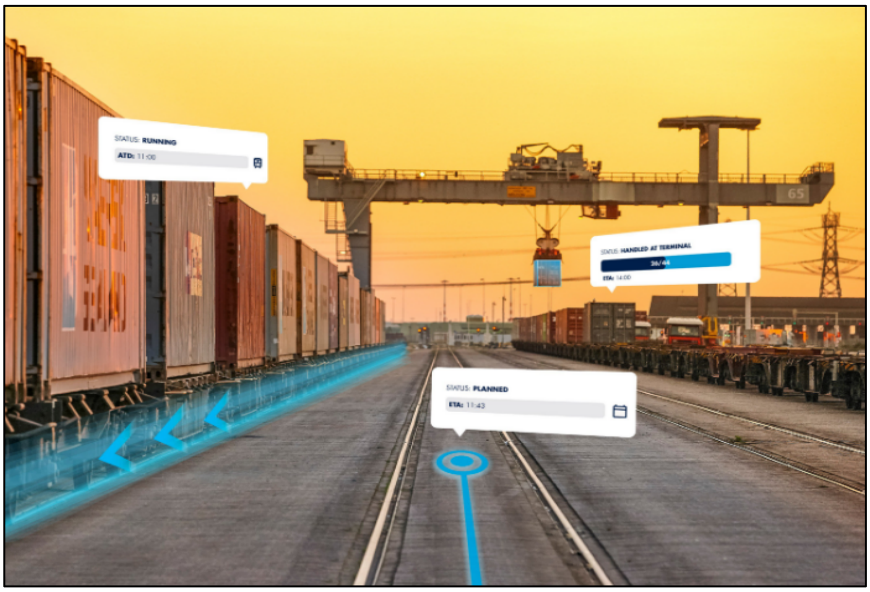


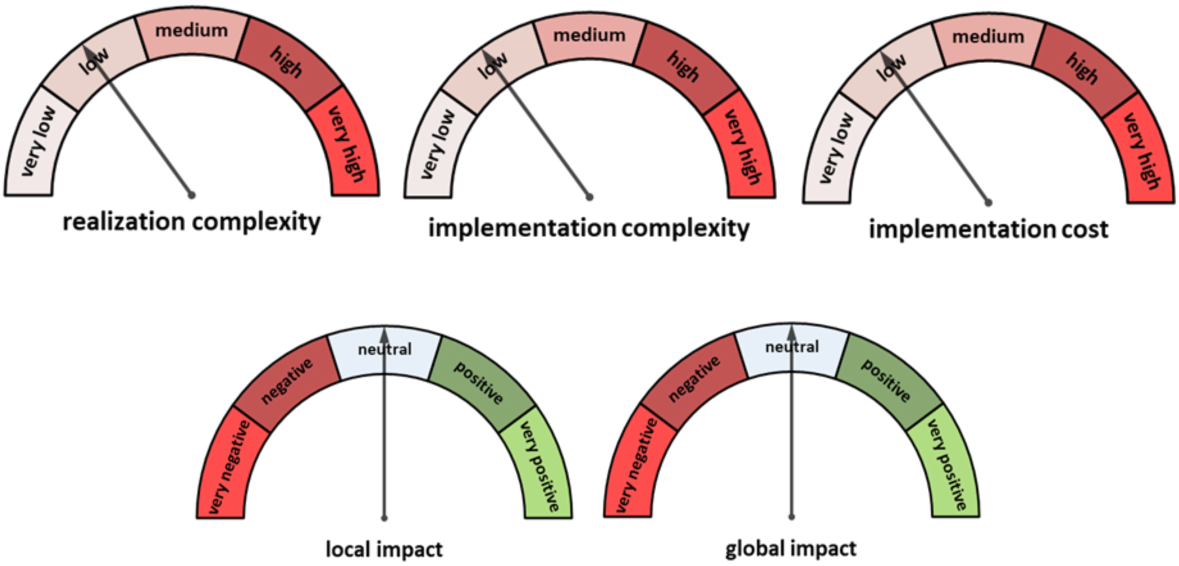
Figure 13. OnTrack[39].

[39] https://www.portofrotterdam.com/en/port-forward/products/ontrack

SWOT strategies

Converting W into S	Qualified staff to manage the application.
Converting S into W	Application crash. No software updates.
Converting T into O	Creating a digital infrastructure that communicates in real time with all the participants involved.
Converting O into T	Do not collect funds.
Matching O to S	Collecting EU funds for industrial digitalization.
Avoid T and W	Contact a certified software company that is in charge of maintenance and updates.

Solution indicators



Solar concentrator farm

Main objectives

Energy savings and air quality.

Case studies

Port of Antwerp, Belgium.

Solution

A solar concentrator farm (CST) works by concentrating sunlight by parabolic mirrors and converting it directly to heat. The temperatures reached can be as high as 400°C, thus providing high-grade heat that can be used in industrial processes. The heat can be stored in insulated containers so that it is also available for use at night. The steam produced is used for cleaning and heating tanks and containers. The CST farm with 1100 m^2 of parabolic reflectors will replace 500 MWh of gas consumption annually[40].

Solution improvement on

Weaknesses	Improvement
Contribution to the environmental pollution of the area	High
Small to medium ports	Medium
Seasonal ports in passengers transport	-
Traffic and infrastructural problems	-
Conflicts between port operations and existing land uses	Low

Figure 14. Solar concentrator farm[41].

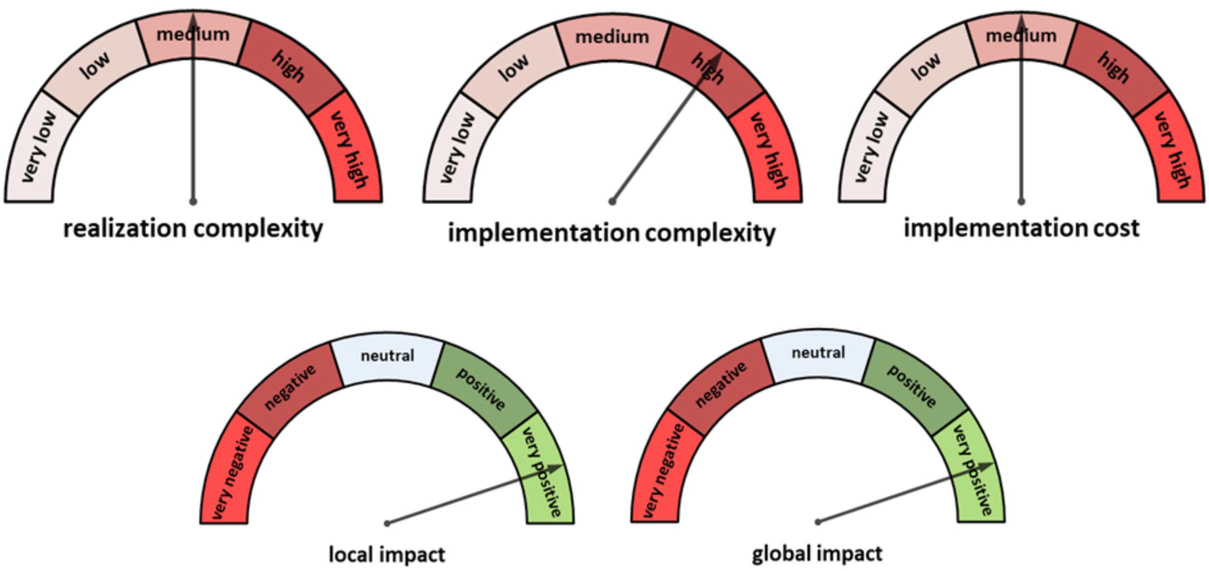
[40] https://www.greenport.com/news101/energy-and-technology/pioneering-solar-heat-project-launched

[41] https://newsroom.portofantwerp.com/pioneering-eco-friendly-project-for-solar-heat-in-the-port-of-antwerp

SWOT strategies

Converting W into S	Heat can be stored so that it is also available for use at night.
Converting S into W	With a sharp reduction in container traffic. If the steam consumption/production ratio is not balanced.
Converting T into O	Informing that consumption reduction improves environmental quality.
Converting O into T	Do not collect funds.
Matching O to S	Collecting EU funds.
Avoid T and W	Reduce construction time.

Solution indicators



Water turbine

Main objectives

Energy savings and air quality.

Case studies

Port of Antwerp, Belgium.

Solution

The turbine installed in the Port of Antwerp measures 2 m in diameter and stands 4 m tall. It has been installed in a 2.5 m wide drainage canal alongside the Kallo sluices and is expected to generate around 120 kW of power. The intention is to add a further fifteen to twenty turbines in other such canals in the port. There are also plans to install turbines in the southern Netherlands. In a vertical axis water turbine, the blades revolve vertically in the water around an upright, central shaft containing the generator. Pitch control is developed for maximum efficiency and a high fish friendliness, developers claim, while also enabling energy extraction from water currents at lower speeds[42].

Solution improvement on

Weaknesses	Improvement
Contribution to the environmental pollution of the area	-
Small to medium ports	High
Seasonal ports in passengers transport	-
Traffic and infrastructural problems	-
Conflicts between port operations and existing land uses	-

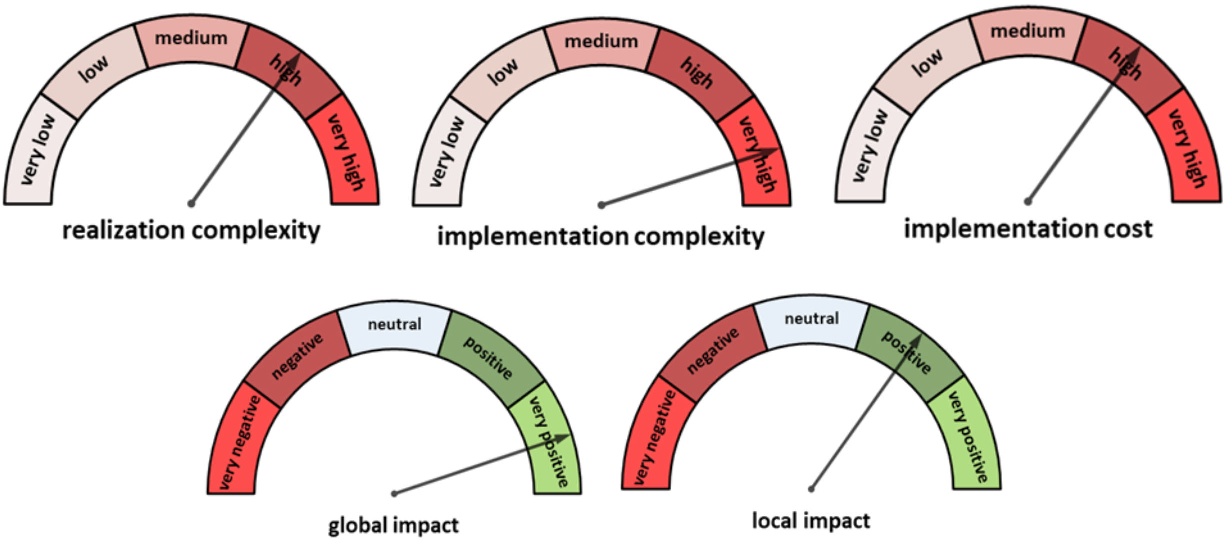
Figure 15. Water turbine[42].

[42] https://www.deingenieur.nl/artikel/dutch-water-turbine-in-the-port-of-antwerp

SWOT strategies

Converting W into S	Producing energy with low flow speed.
Converting S into W	Not operating efficiently. Potential impact on landscape and fauna.
Converting T into O	To inform the public of the positive project outcomes.
Converting O into T	Do not collect funds. Any incompatibilities with Community environmental legislation.
Matching O to S	Collect European funds.
Avoid T and W	Involve local authorities, including the inhabitants. Respect the environmental normative restraints.

Solution indicators



Flexible transport systems

Main objectives

Sustainable mobility and tourism.

Case studies

European Ports in the "LAST MILE" project.

Solution

Flexible transport systems (FTS) may be the answer to transport accessibility challenges in rural areas. Flexible transport services are defined as services that only operate on demand. Operation on demand in this context includes call/dial systems (i.e., hailed shared taxi), seasonal/temporary systems (i.e. occasional bus/train) and other forms of on-demand transport (e.g., sharing and pooling systems). Therefore, it comprises services that can be summarized as enhanced public transport services (also flexible public transport services) like a hailed shared taxi service and other flexible transport services such as car- and bike-sharing or carpooling which are not part of public transport in the narrower sense. In the LAST MILE project, the main feature of the FTS is that the service operates on demand only. FTS systems can play a complementary role to existing regular public transport services or can operate as completely new transport solutions. The advantage of the FTS is a far more efficient adaptation of the service to the actual needs of passengers. This enables to provide an affordable service to smaller flows of passengers, and at the same time excludes empty trips or low occupancy of vehicles, which are regular problems in conventional transport systems. It is also possible to extend the scope of the system and to cover larger areas and provide public transport to a larger population[43].

Solution improvement on

Weaknesses	Improvement
Contribution to the environmental pollution of the area	Low
Small to medium ports	Medium
Seasonal ports in passengers transport	Very High
Traffic and infrastructural problems	Low
Conflicts between port operations and existing land uses	-

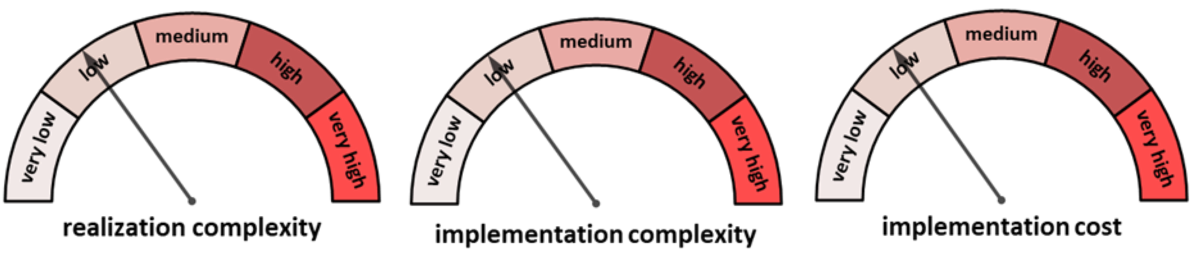
Figure 16. Flexible transport systems examples[43].

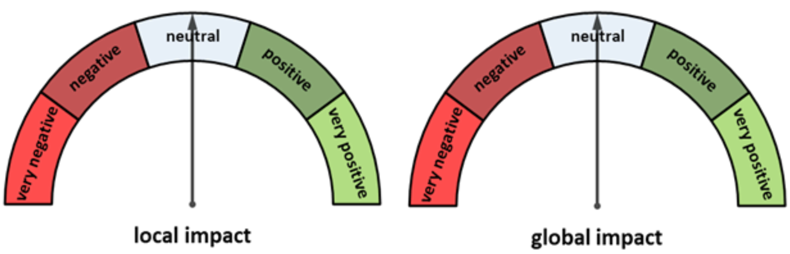
[43] LAST MILE – Sustainable mobility for the last mile in tourism regions

SWOT strategies

Converting W into S	Advertising the flexible transport service may increase the touristic attractiveness of the area.
Converting S into W	Discount and special price reserved for local inhabitants.
Converting T into O	Increasing the number of tourists. Reduction of seasonal tourism.
Converting O into T	Lack of support from local authorities.
Matching O to S	Collect funds and partnerships.
Avoid T and W	Involve local authorities in the project.

Solution indicators





Port call optimization

Main objectives

Intermodality.

Case studies

Port of Rotterdam, Netherlands.

Solution

The port of Rotterdam developed a new application (i.e., Pronto) that shipping companies, agents, terminals, and other service providers can use to optimally plan, execute and monitor all activities during a port call. This includes pilotage, terminal use, and bunker services. The timeline displays all events/activities during the port call: from the vessel's arrival and stay in the port to its departure from the port. The progress and status are continually adjusted in real time. On their own dashboards, users can easily filter the available data and zoom in on the timeline of an individual port call. They can use this information to plan and execute their activities much more efficiently than in the past[44].

Solution improvement on

Weaknesses	Improvement
Contribution to the environmental pollution of the area	Medium
Small to medium ports	Medium
Seasonal ports in passengers transport	-
Traffic and infrastructural problems	High
Conflicts between port operations and existing land uses	-

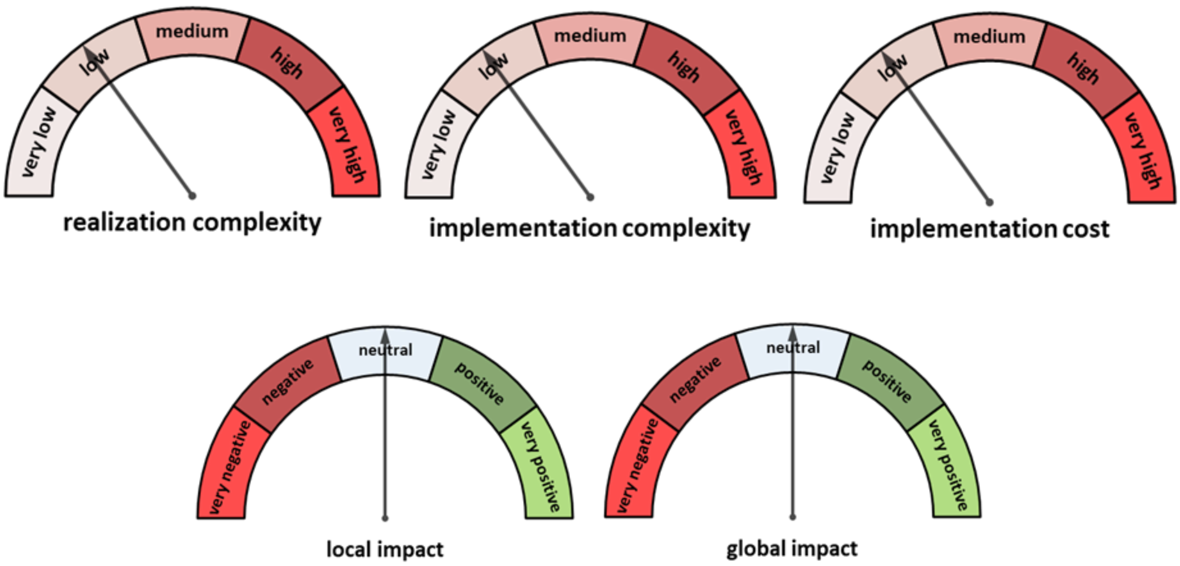
Figure 17. Pronto application[44].

[44] https://www.portofrotterdam.com/en/shipping/sea-shipping/other/port-call-optimisation

SWOT strategies

Converting W into S	Qualified staff to manage the application.
Converting S into W	Application malfunctions/crashes. No software updates.
Converting T into O	Creating a digital infrastructure that communicates in real time with all the participants involved.
Converting O into T	Do not collect funds.
Matching O to S	Collecting EU funds for industrial digitalization.
Avoid T and W	Contact a certified software company that is in charge of maintenance and updates.

Solution indicators



Incentives for LNG ships and ships with waste recovery on board

Main objectives

Waste management and air quality.

Case studies

Port of Civitavecchia, Italy.

Solution

The port of Civitavecchia wanted to "reward" shipowners who choose the most advanced technologies in terms of reducing ships' atmospheric emissions with incentives that reduce the costs related to the transfer of waste produced by ships. Among the "awarded" eco-sustainable technologies there is also LNG[45].

Solution improvement on

Weaknesses	Improvement
Contribution to the environmental pollution of the area	High
Small to medium ports	Medium
Seasonal ports in passengers transport	-
Traffic and infrastructural problems	-
Conflicts between port operations and existing land uses	-

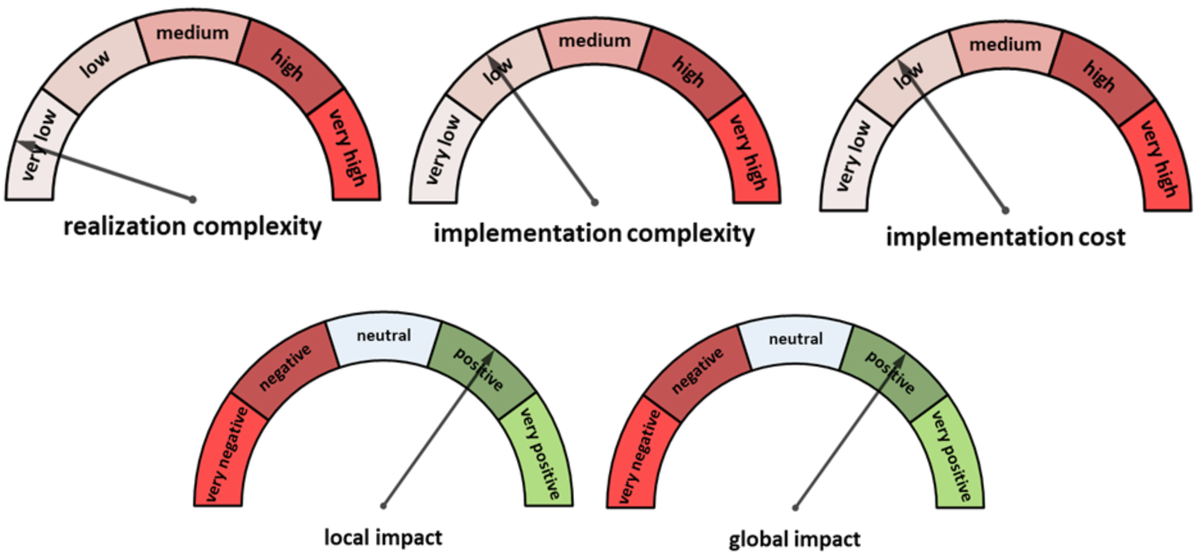
Figure 18. LNG ship "Aida nova"[15].

[45] https://civitavecchia.portmobility.it/it/green-port-arriva-civitavecchia-la-prima-nave-alimentata-gnl

SWOT strategies

Converting W into S	Inform shipowners about the economic viability of the project.
Converting S into W	Poor participation of shipowners in the project.
Converting T into O	Eco-sustainable policy that complies with current regulations.
Converting O into T	Allocate incentives that are not profitable for shipowners.
Matching O to S	Collecting EU funds for eco-sustainable technologies.
Avoid T and W	Analyse the trends of the ports that have already put in place incentive policies.

Solution indicators



Light emitting diode (LED) technology system

Main objectives

Energy savings and use of renewables.

Case studies

Port of Venice, Italy.

Solution

In 2010 Venice port authority has adopted a LED technology system in the passengers' terminal, saving 70% of energy in comparison to traditional light emitting systems. In addition, since August 2015, another LED system, supported by solar panels, is in use along 15 km of one of the main port canals[46].

Solution improvement on

Weaknesses	Improvement
Contribution to the environmental pollution of the area	Low
Small to medium ports	-
Seasonal ports in passengers transport	-
Traffic and infrastructural problems	-
Conflicts between port operations and existing land uses	-

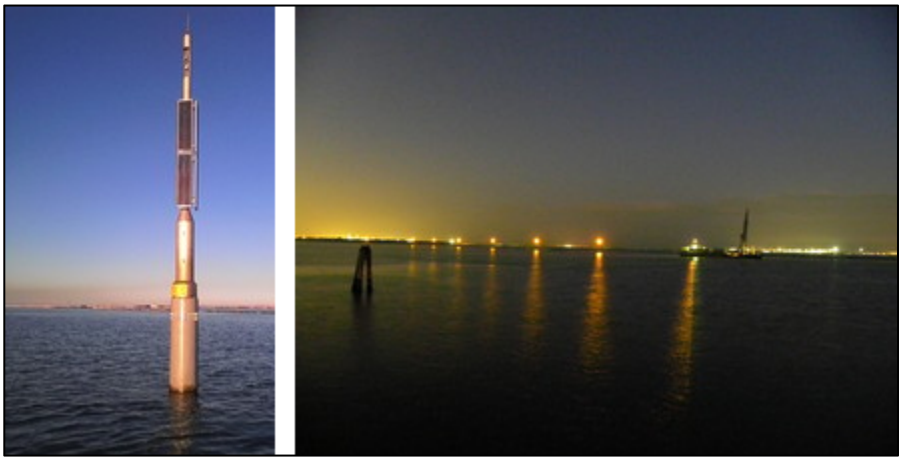


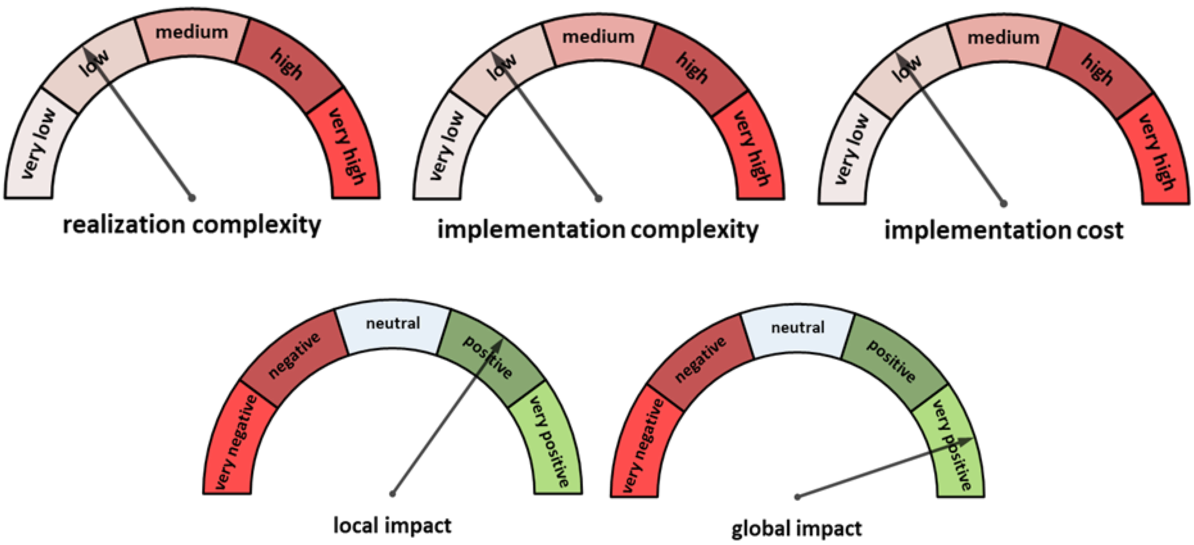
Figure 19. LED technology[46].

[46] https://www.port.venice.it/en/energetic-efficiency.html

SWOT strategies

Converting W into S	LED technology allows the enhancement of lighting and the achievement of energy savings.
Converting S into W	Failure to use renewable energy to power the LED system.
Converting T into O	Funds for energy improvement.
Converting O into T	Do not collect funds.
Matching O to S	Collect EU funds.
Avoid T and W	An alternative emergency system available in case of failure.

Solution indicators



Water management

Main objectives

Water quality.

Case studies

Port of Nantes – Saint-Nazaire, France.

Solution

The Port built a water treatment plant (200 m3/h) with sieving and injection of chemical reagents. Partnership with the municipality for the construction of a wastewater treatment plant for both urban water and wastewater from the port area (economies of scale and a significant reduction of environmental impact. Agreement with terminal operators to limit input of pollutants and financial penalties for noncompliance with the agreement[47].

Solution improvement on

Weaknesses	Improvement
Contribution to the environmental pollution of the area	High
Small to medium ports	High
Seasonal ports in passengers transport	-
Traffic and infrastructural problems	-
Conflicts between port operations and existing land uses	Very High

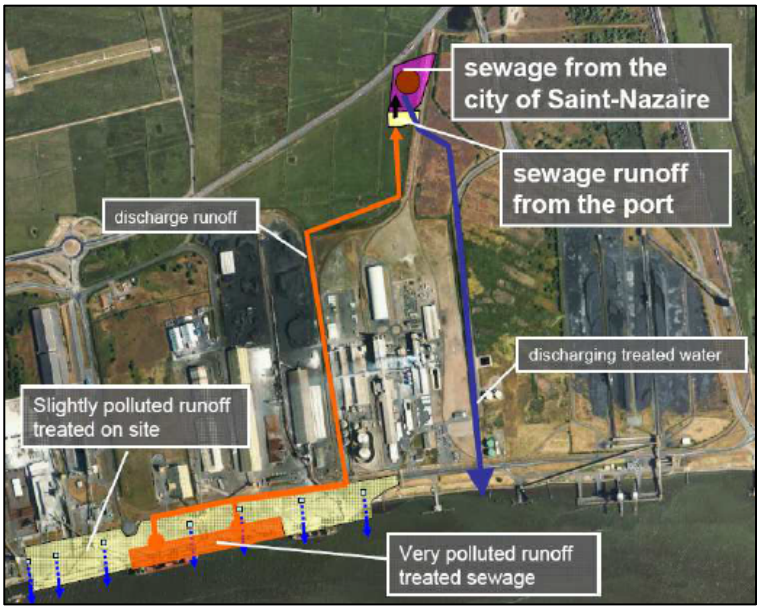


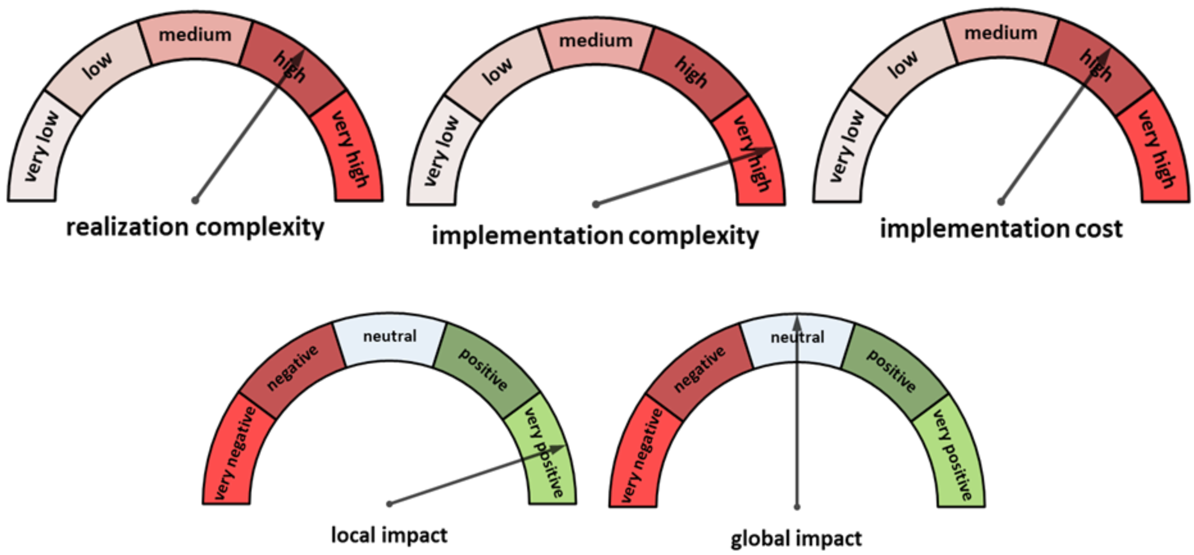
Figure 20. Scheme of storm water runoff treatment of Port of Nantes Saint-Nazaire[47].

[47] ESPO Green guide; Annex 1: Good practice examples.

SWOT strategies

Converting W into S	Reduction of environmental impact.
Converting S into W	Producing odorous emissions beyond the established limits.
Converting T into O	Informing local authorities and inhabitants about the necessity of improving runoff water collection and treatment.
Converting O into T	Do not collect funds.
Matching O to S	Collect funds.
Avoid T and W	Inform about money savings. Inform about environmental improvements.

Solution indicators



Noise Control

Main objectives

Noise management.

Case studies

Port of Auckland, New Zeland.

Solution

Noise-control initiatives include:
- Additional soundproofing and noise-reduction features fitted to new straddle carriers and other equipment;
- The elimination of or reductions in the majority of warning sirens on heavy machinery;
- Ship horns no longer being used to signal departures from the container terminal; ship horns are used only for safety reason (e.g., foggy conditions);
- The elimination of rail crossing alarms;
- The minimization of rail shunt moves;
- Fitting of alarm mufflers to two gantry cranes;
- Working with the shipping lines to further reduce the noise from ship generators;
- Seeking to ensure that new developments in close proximity to the port have adequate soundproofing[48].

Solution improvement on

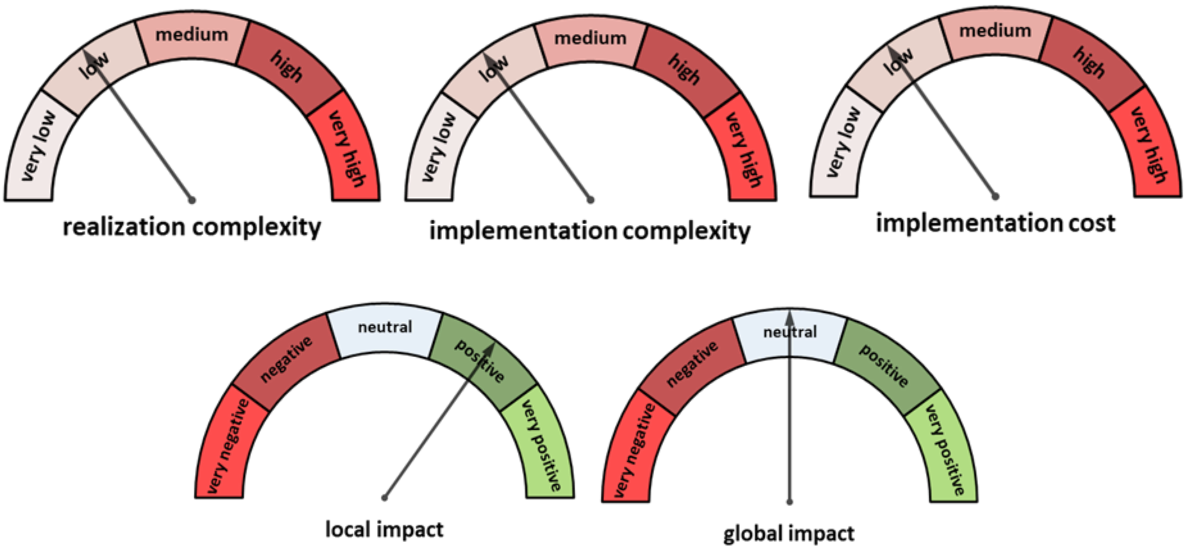
Weaknesses	Improvement
Contribution to the environmental pollution of the area	High
Small to medium ports	Medium
Seasonal ports in passengers transport	-
Traffic and infrastructural problems	-
Conflicts between port operations and existing land uses	High

[48] http://www.poal.co.nz/sustainability/environmental-management/noise-traffic-management

SWOT strategies

Converting W into S	Need for well-trained port operators.
Converting S into W	Untrained staff. Need for further measures to prevent workplace safety hazard.
Converting T into O	Increased environmental reputation.
Converting O into T	Potential conflict with safety requirements.
Matching O to S	Obtaining project approval from local authorities, inhabitants, and operators.
Avoid T and W	Evaluation of the trial period of the strategy.

Solution indicators



General airport and port strategies

Practical sustainable applications to achieve carbon reductions at airport and port infrastructures.

Solution	Brief description	Port reference case studies	Airport reference case studies
Solar panels	Solar panels installed in different areas of the port/airport (e.g., rooftops of buildings and warehouses) for generating renewable energy.	Rotterdam, Amsterdam, and Gothenburg	Copenhagen, and Helsinki Airport
Geothermal heat pump/ Aquifer thermal energy storage[49]	Renewable thermal energy for large heating and cooling loads. Cooling/heating system employs a water-based thermal energy storage system that stores heat/cold in ground- water reservoirs.	Marseille	Paris-Orly, Nashville, Calgary, Stockholm-Arlanda, and Copenhagen Airport
Energy monitoring system	Monitoring system of the energy consumption of airport/port equipment, buildings and other facilities for supporting decision-making and implementation of measures for improving energy efficiency.	Valencia, Koper, and Jade Weser Port	Copenhagen Airport
Smart grid	Electricity network based on digital technology that can cost-efficiently integrate the behaviour and actions of all generators and consumers that are connected to the grid.	Antwerp	-

[49] Baxter et al. (2018). An assessment of airport sustainability, Part 2—Energy management at Copenhagen Airport. *Resources*, *7*(2), 32.

Daylighting strategy	A daylighting strategy can reduce electricity for lighting and peak electrical demand, cooling energy and peak cooling loads, maintenance costs associated with lamp replacement, and electrical service to the building. Maximize south glazing and minimize east- and west-facing glass[50].	Yokohama	Denver, and San Francisco Airport
Green roofs	Green roofs are covered with vegetation and a growing medium planted over a waterproofing membrane. When weight restrictions need to be considered, it is possible to utilize substrates that provide an adequate nutrient supply with relatively low specific weight. Main environmental goals: absorbing rainwater, providing insulation, and helping to mitigate the heat island effect in the built environment.	Värtahamnen, and Copenhagen	Frankfurt, Ibiza, Munich Airport, Paris Orly, and Bordeaux–Mérignac Airport
Concrete pavement instead of asphalt	Pavers are lower maintenance and generally have a longer lifespan compared to asphalt.	Värtahamnen	-
LED	Light emitting diode (LED) is a highly energy efficient lighting technology.	Venice, Hamburg, and Los Angeles	Stockholm Arlanda, Copenhagen, Schiphol, and Oslo Airport

Table adapted from Sdoukopoulos et al.[51].

[50] https://www.lrc.rpi.edu/programs/daylighting/pdf/guidelines

[51] Sdoukopoulos et al. (2019). Energy Efficiency in European Ports: State-Of-Practice and Insights on the Way Forward. Sustainability, 11(18), 4952.

Conclusions

This report presents replicable operational and technological solutions aimed at improving intermodal connections and reducing the environmental impact of airports and ports. For small to medium sized airports and ports, there is a full basket of best practices and green technologies ready to use.

To select pilot actions relevant to the environmental footprint of airport and port infrastructures, the following points should be considered:

- environmental goals that can be achieved implementing the solution;
- main weaknesses according to the SWOT analysis of the infrastructure;
- how the solution is expected to positively act on the weakness of the infrastructure;
- degree of improvement deriving from implementing the solution;
- SWOT strategies to identify strategic directions, scenarios, and best practices related to environmental externalities deriving from operations at the infrastructure.
- Indicators such as design complexity, Implementation complexity, Implementation cost, Local impact, and global impact.