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Providing resilience due to adverse weather events: A cost-benefit analysis for the case of the Milan Malpensa airport in Italy

Francesca Pagliara [a,*], Marco Zingone [b]

[a] Department of Civil, Architectural and Environmental Engineering, University of Naples Federico II, Italy
[b] PwC, Italy

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ABSTRACT

Climate change is one of the key challenges for the future of human society and the planet. A strong coordination of political strategies, both nationally and internationally, is necessary, as well as a change in the lifestyles of large parts of the population.

In this context, this paper aims at introducing an application of the Cost-Benefit Analysis (CBA) for providing resilience of a transport infrastructure. Milan Airport Malpensa in the north of Italy has been studied with the objective of limiting serious economic and social damage caused by an interruption of the service following adverse weather events.

1. Introduction

In a context in which the climate is constantly changing together with the increase in the occurrence of extraordinary meteorological events, infrastructures are subject to negative events. Specifically, in recent years, in certain areas, calamitous events have occurred that have caused collapses, complete or partial, within the infrastructural networks.

To cope with these calamities, public administrations, associations, organizations and other bodies, collaborating with each other, aim at restoring the original performance of the systems.

In particular, the "critical infrastructures", i.e. those systems related to communications, energy, health, information technology, transport and water systems that provide basic services for the economy, security and stability of a nation, should be safeguarded from disasters.

Transport systems are essential for the well-being of the community, since due to the extensive interconnection with all other critical infrastructures, especially in adverse conditions, they provide the possibility of evacuation, rescue operations and facilitate the restoration of community services.

To evaluate the characteristics and potential of the territory or of a project to cope with the disaster, measures have been introduced, such as:

- sustainability: it is a very varied concept that includes social, economic and environmental aspects, in general and in the field of transport systems, it deals with the process of change such the exploitation of resources, the direction of investments, the orientation of technological development and institutional changes which are consistent with the future as well as the current needs.
- vulnerability: in relation to a transport system, this concept can be defined as the susceptibility to events that can lead to considerable reductions in the service of the transport system or, more simply, as the company's risk of interruptions and degradation of the transport system. To measure the level of vulnerability of an infrastructure, vulnerability studies have been developed aiming to find the weaknesses of a system, estimating the probabilities that they will lead to serious deterioration and the related consequences. The term vulnerability is often used even though there is no attempt to determine the probability of perturbation. A vulnerability study can help the system manager identifying critical elements and possible preventive measures. Vulnerability studies, as opposed to resilience ones, are more limited and focus mainly on how the robustness of a system can be strengthened.
- resilience: it can be defined as the ability to resist, absorb, adapt and recover quickly from shocks, interruptions and deliberate attacks.

In recent years, research related to the issue of resilience has undergone an exponential increase, as have those relating to the specific

* Corresponding author.
E-mail addresses: fpagliar@unina.it (F. Pagliara), marcozingone98@libero.it (M. Zingone).

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sector of transport infrastructures. In general, resilience can be viewed in two different ways: output oriented and process-oriented.

The first considers resilience as an output index, designed to measure one or more characteristics of the system (e.g., adaptation, recovery of performance over time, etc.); the second considers it as a process (or approach), which aims at increasing the resilience of the system through the identification of specific actions. Based on the above, we could define resilience as the ability to resist, absorb, adapt and quickly recover from shocks, interruptions and deliberate attacks. From this definition it is possible to understand that the benefits of a resilient infrastructure derive from its ability to minimize the costs of interruptions.

For infrastructures, resilience is aimed at evaluating their functioning following the occurrence of an external disturbance, which can depend on both long-term climate change and the impact of single or repeated extreme events.

Despite this, resilience depends on characteristics that the system has also in the pre-, during and post-event phases, involving in the evaluation technical, managerial, structural, and non-structural aspects based on natural characteristics of the context. Other aspects that should be considered to obtain a resilient system are all the possible interactions that could occur among all its components and the analyse of how they react to the disturbing event. For this reason, a possible measure of resilience could be the ability to create alternative routes, with the aim of improving the speed of response to disasters generated by a disruptive event.

In Table 1 some examples of the works reported in the literature on the resilience of infrastructure are reported.

In this paper a Cost-Benefit Analysis (CBA) is reported with the aim of providing the resilience of a transport infrastructure, specifically an Italian airport, the one of Malpensa in the North of Italy. This paper is organised as follows. Section 2 deals with a literature review concerning studies related to the application of the CBA including the resilience issue. Section 3 deals with the case study description. Section 4 describes the results of the financial analysis. Section 5 provides a socioeconomic analysis, while 6 reports some future research directions.

2. CBA of providing resilience: a review

Cost Benefit Analysis (CBA) is an established economic approach for comparing the benefits and costs of a given project or activity. CBA involves identifying, quantifying, monetising, and summing in monetary units the value of incremental costs and benefits over the life of a project. The importance of CBA for decision makers is that its results provide a quantitative measure to understand whether the realization of given project is worth for the society.

The socioeconomic costs of infrastructure damage and lost functionality as a result of natural disasters, such as climate change or a major attack, are far greater than the cost of improving infrastructure resilience to typical events and properly maintaining it (Kovarik et al., 2020).

According to the ADBI (2020), building resilient infrastructure systems is fundamental since: (i) advocates for an urgent review of the integration of resilience into cost-benefit analyses and the use of other economic appraisal methodologies for infrastructure projects; and (ii) recommends prioritizing public and private investments in resilient infrastructure projects and projects that adapt existing assets to risks, thus improving their resilience.

Resilience is "*the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions*" (UN, 2009).

Extending the OECD's (2018) definition of climate-resilient infrastructure, a resilient infrastructure system is one that is planned, designed, built, and operated in a way that anticipates, prepares for, and adapts to changing conditions. These conditions can include not only

Table 1
Examples of works on the resilience of infrastructure.

Jha et al. (2013)	Building Urban Resilience: Principles, Tools and Practice. This work summarises guiding principles, tools, and practices in key economic sectors that can facilitate incorporation of resilience concepts into the decisions about infrastructure managers.
Brown et al. (2014)	Review of resilience of transport networks. This work summarises the problems that transport networks in the UK are having due to natural hazards and makes recommendations of how to deal with them.
Hughes and Healy (2014)	Measuring the Resilience of Transport Infrastructure. This work proposes a resilience measurement framework that broadly covers both the technical and organisational dimensions of resilience and breaks these down into specific principles and measures, which can be used to assess resilience qualitatively.
Proag and Proag (2014)	"The vulnerability of a system is best addressed by introducing some form of resilience, hard or soft, to the risks associated with the physical, social and economic aspects of the system's ability to cope with disturbing events.
Nocera et al. (2015)	In their study, authors build a database of over 700 unique observations derived from 60 studies on the economic valuation of GHG emissions. Following that, they apply a meta-analysis to evaluate the variation in emissions costs, therefore significantly reducing overall uncertainty.
Prior (2015)	Indicators of resilience for critical infrastructure. This work includes suggestions as to possible indicators of the resilience of critical infrastructures.
Theocharidou and Giannopoulos (2015)	Critical infrastructure protection. This work describes a risk assessment methodology for critical infrastructures, presenting an overview of risks.
US Department of Transportation (USDOT, 2015)	Vulnerability assessment. This work describes the functioning of an Excel tool developed to assess infrastructure vulnerability.
Adey et al. (2016)	"Ensuring acceptable levels of infrastructure-related risks due to natural hazards with emphasis on stress tests". This work gives a guideline of how to establish simulations frameworks for the evaluation of resilience.
Nocera et al. (2017)	The quantification of CO2 emissions from road transport was computed with the adoption of a micro approach, especially at the urban level, despite the computational efforts required and the technical difficulties to model driver behaviors.
Taylor, M. (2017)	Vulnerability analysis for transportation networks. This work reviews the range of existing approaches to network vulnerability and identifies the application of each approach, illustrating them with case studies from around the world
Figueiredo et al. (2018)	An approach to strengthen and monitor urban resilience. This work proposes indicators to be used to monitor the progress of urban areas in becoming more resilient.
Hackl et al. (2018a)	Determination of near-optimal restoration programmes for transportation networks following natural hazard events. This work focuses on explicitly modelling the reconstruction of transportation networks following a natural hazard.
Hackl et al. (2018b)	"Estimating network related risks: a methodology and an application for roads". This work includes a detailed simulation-based risk assessment for a road network in the region of Chur, Switzerland, from the simulation of rainfall patterns to the quantification of lost service through the entire restoration period.
Lam et al. (2018)	"Stress tests for a road network using fragility functions and functional capacity loss functions". This work focuses on establishing steps to be used when running simulations to verify the resilience of transport infrastructure networks.

(*continued on next page*)

Table 1 (*continued*)

Neetesh et al. (2018)	A mathematical approach to the measurement of resilience. This work proposes resilience metrics to describe the recovery curve.
Ale et al. (2021)	"There is no real basis for any estimate of the value of a statistical life, the values employed in cost-benefit analyses therefore only seem to serve the purpose of dissembling, concealing that the decision is taken on grounds other than considerations of avoiding loss of human lives, or even that potential harm to humans was not even considered.

Source: Authors'elaborations adapted from Adey al. (2021) and integrated with other studies

traditional risk management approaches, but also aging, technological adaptation, climate change, new applications, and socioeconomic evolution.

Adverse events, whether natural or man-made, not only damage but also disrupt the functionality of physical infrastructure assets. According to the World Economic Forum, one of the top five global economic risks is a failure to adequately invest in infrastructure networks (WEF, 2020). It also discovered that the majority of the top ten most likely risks (extreme weather, climate action failure, natural disasters, cyber attacks, and pandemics) could have an impact on transportation infrastructure.

For example, disruptions in transportation infrastructure systems have a variety of effects on households and businesses, including lost sales, delayed supplies and deliveries, freight delay costs, congestion and lost time, increased fuel and operating costs for road users and goods due to longer journeys on alternative or lower capacity routes, and lost revenue collection on toll roads.

Disruptions also have an impact on the economy, such as decreased competitiveness and productivity, lower investment, less innovation, environmental externalities, decreased access to health care, and potential air pollution due to increased congestion or the loss of the most efficient mode of transportation for a given commodity (e.g., inland waterways for agricultural products vs. air freight for pharmaceuticals).

These have an impact on both public and private asset owners, reducing the region's economic and social efficiency. Physical infrastructure failure or a significantly reduced level of service caused by acute natural events (e.g., hurricanes, earthquakes, massive flooding, uncontrolled fires) or chronic stressors (e.g., coastal surge from rising sea levels, ground movements caused by climate variations) have a direct impact on tax revenues.

Adequate resilience investments have the potential to reduce the overall impact of disasters on businesses, communities, and governments. The World Bank, for example, estimates that the overall net benefit of investments in infrastructure resilience in developing countries could reach US$ 4.2 trillion over the life of infrastructure assets; estimates suggest a US$ 4 return on investment in infrastructure resilience (Voegele, 2019). Hazards and threats can also have an impact on multiple economic sectors when key dependencies cause failure in one sector to spill over into others.

Recent studies (Hallegatte et al. 2019a, 2019b) based on over 3000 scenarios show that the urgency of designing resilient infrastructure is clear when considering natural hazards: delaying global action on resilience to 2030 is costly in most scenarios, with a median value of US$ 1.0 trillion in potential losses. When climate change is factored into these scenarios, the median cost of delaying action for ten years nearly doubles. Biodiversity losses and ecosystem damage should be investigated further. Several recent studies (Miyamoto International, 2019; Koks et al., 2019) highlight the economic issue of adapting infrastructure (new construction or rehabilitation) to specific risks. The additional cost is determined by the risk, asset type, and location. For example, increasing the resilience of a road to flooding by improving the drainage system costs only a few percent more, whereas increasing the level of a railway line can cost up to 50% more.

According to Hallegatte et al. (2019a), strengthening infrastructure assets vulnerable to natural disasters is a very sound investment, with a cost-benefit ratio greater than one in 96% of cases and greater than four in half of them. Climate change emphasizes the importance of fortification and more than doubles the cost-benefit ratio.

More resilient and less vulnerable assets can be achieved through improved maintenance processes, which result in lower life cycle costs. When the full life cycle costs of the infrastructure are considered, increasing infrastructure resilience frequently benefits the asset owner. While improving operating and maintenance conditions is desirable for resilience, poor maintenance can increase infrastructure capital costs by 50%. (Rozenberg and Fay, 2019).

According to Kornejew et al. (2019)' analysis of OECD countries, every additional $ 1.0 spent on infrastructure maintenance is as effective as $ 1.5 of new investment.

Timely maintenance is a cost-effective option for increasing resilience that lasts the lifetime of the infrastructure, allowing for continuous operation. Human engineering and construction create nature-based solutions to reduce risk by working in tandem with natural processes and drawing on the capacity of natural features, such as wetland restoration, biogenic reefs, beaches, and dunes that help reducing the impacts of storm surge (International Union for Conservation of Nature, https://www.iucn.org/). These solutions demonstrate how improving natural capital works in tandem with infrastructure resilience to provide a cost-effective response to climate change while also delivering a variety of other societal benefits (IDB, 2019).

An interesting study proposed by Nocera et al. (2015) deals with the delicate issue of quantifying the economic impact of greenhouse gas (GHG) emissions. Current figures, which are largely provided by Impact Assessment Models, can range from $-10.00/tC to $7243.73/tC (a six-order-of-magnitude range). It is quite difficult to choose an appropriate monetary value within this range. In their study, authors build a database of over 700 unique observations derived from 60 studies on the economic valuation of GHG emissions. Following that, they apply a meta-analysis to evaluate the variation in emissions costs, therefore significantly reducing overall uncertainty.

In Nocera et al. (2017) to quantify CO2 emissions from road transport, it is suggested the adoption of methods, based on transport modelling and carbon modules. These methods are named micro and macro approaches. Their distinction is based on the temporal and spatial horizons. In their paper, authors present these methods and discuss their appropriateness. They conclude that the adoption of the micro approach, is quite promising especially at the urban level, despite the computational efforts required and the technical difficulties to model driver behaviors.

Resilience is context-dependent and requires taking into account non-resilience costs as well as significant resilience improvement costs. The total cost-benefit ratio of improving resilience appears to be largely beneficial over the lifetime of the infrastructure.

3. The case study

For the implementation of the project aimed at the resilience improvement of the Milan Malpensa airport against natural hazards by implementing infrastructure upgrade and a smart monitoring system in a multi -risk framework hereafter, the society SEA Airport applied for funds allocated by the European Union following a call launched by the European Climate, Infrastructure and Environment Executive Agency (CINEA) to submit proposals under the Connecting Europe Facility (CEF) Transport sector.

Specifically, the project aims at improving the resilience of Milan Malpensa Airport (MXP) to climate change and natural disasters through a five-years process of the infrastructure modernization. Therefore, this opportunity will increase the resilience of Milan Malpensa Airport through the implementation of infrastructure enhancements and the development of an intelligent monitoring system. The studies and works planned as part of the project will mitigate both the flooding and the seismic risks.

The duration of the project is set at 5 years (2022-2026) and comprises the development of five Work Packages (WP):

- Management and Coordination activities.
- Study and Design activities.
- Sub-activities focused on improving the drainage system to increase the resilience of the infrastructure to flash floods.
- Specific works for seismic risk reduction based on the results of seismic vulnerability assessments and further investigation and testing of structures.
- Development of an intelligent monitoring system in a multi-risk framework. This system will include:
  - o the deployment of sensors within the airport;
  - o the implementation of remote management of the monitoring system including early warning and alarms;
  - o testing the intelligent monitoring system.

Milan Malpensa Airport is located in northern Italy (Lombardy region), specifically in the province of Varese. According to ISTAT (Italian census) data, this airport is the second Italian airport in terms of passenger traffic and first in terms of cargo traffic, having reached in 2019 (latest available data not influenced by the effects of the Covid-19 pandemic) approximately 29 Mln passengers and 0.55 Mln tonnes of cargo respectively, equal to approximately 51.9% of the cargo transported by Italian airports. Furthermore, at the European level as reported in Fig. 1 it is classified as a node of the TEN-T Core Network and it is located at the two TEN-T Core Corridors:

- the Rhine-Alps Corridor;
- the Mediterranean Corridor.

The overall objective of the project is in line with EU policy priorities, including safe mobility, as outlined in the call for proposals for the Connecting Europe Facility - Transport (CEF2). The proposed project also responds to the requirements of the National Strategy for Adaptation to Climate Change (SNAC), which aims at optimizing existing networks also with a view of achieving one of the key objectives of the EU 2030 Agenda, i.e. construction and development of quality, reliable, sustainable and resilient infrastructure.

The project will contribute to the development of the trans-European transport network through the modernization of the existing transport infrastructure and the promotion of the efficient use of the network. Moreover, it will pursue the following objectives as set out in the Article 4 of Regulation 1315/2013.

- Cohesion: the objective refers to the reduction of infrastructure quality gaps between Member States. The investment proposed by SEA SpA aims at promote and building resilient infrastructure in line with the European standards.
- Efficiency: the objective is to promote the efficient use of new and existing infrastructures through the application of innovative technological and operational concepts. The project aims at enhancing the value of the existing infrastructure through the use of the most sophisticated and innovative technologies.
- Increase the benefits for users: the focus is on actions to support mobility in the event of natural or man-made disasters and ensuring accessibility to emergency and rescue services. The main point of the intervention proposal is to increase resilience, which is strongly linked to the issue of climate change adaptation. Indeed, the latter is a major contributor to infrastructure damage and disruption of transport services.

The Project objectives are:

- the improvement of the Milan Malpensa airport sewerage system for flood risk mitigation;
- the enhancement of Passenger Terminal 1 at Milan Malpensa Airport for seismic risk mitigation;
- the development of an intelligent monitoring system for Milan Malpensa airport in a multi-risk framework.

To determine the financial and economic effects of the project in terms of flood and seismic risk mitigation, the following steps were developed in the Cost Benefit Analysis:

- assessment of flooding events in terms of disruption to airport operations. Some key areas of Milan Malpensa Airport, such as Runway 35L, Cargo Area, Terminals T1 and T2 and the airport's internal road system, were severely flooded in 2015 and 2021. The analysis was conducted considering the effects of the flooding that occurred in September 2021 in which there was an interruption of the service for about 3 h.
- Evaluation of seismic events in terms of interruption of airport operations. To define the return period of an earthquake and, consequently, the probability of a seismic event occurring, the last 35 years were analysed in terms of events recorded in the Lombardy Region relating to a seismic intensity between I and IV of the Mercalli Intensity (MMI). To define the return period of an earthquake of seismic intensity greater than IV (MMI), the time horizon of the analysis was extended to 1000 years. During this period, no earthquakes greater than level VI (MMI scale) were recorded. The MMI scale describes the intensity with which an earthquake is felt, starting from level I defined as 'not felt' up to level XII considered 'extreme'. The ratio of two consecutive intensity values in terms of damage is 31.6. The latter was used to define the impact of infrastructure damage. By comparing the estimated return period of an earthquake for the Lombardy Region with the seismic return period of Passenger Terminal 1 at Milan Malpensa Airport, the interruption of service to the airport was calculated, assessed in relation to the estimated damage impact, both with and without the project.

In accordance with the Guide to the Cost-Benefit Analysis (CBA) of Investment Projects developed by the European Commission, 2014 (hereafter 'Guide'), the project evaluation was conducted on both the financial and socio-economic dimensions.

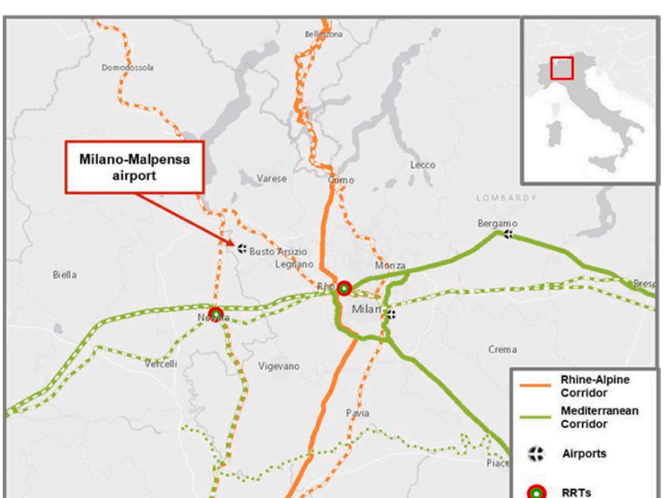


Fig. 1. Location of the project. Source: TENT.

3.1. Scenarios

To quantify the benefits, related to both dimensions, resulting from the implementation of the project, a CBA was conducted using an incremental approach in which the cost-revenue (financial analysis) and cost-benefit (socio-economic analysis) assessments were carried out by comparing two scenarios:

1. Basic scenario: this scenario corresponds to the situation in which the project is not implemented, generating an increased probability of flooding and seismic events;
2. Project Scenario: this scenario corresponds to the context in which the project is implemented with a consequent reduction of the probability of flooding and seismic events occurrence and able to resist to an earthquake of magnitude 8 of the Richter scale.

By comparing the two scenarios, it was possible to analyse the differential effects in terms of cost-revenue, in the financial analysis, and cost-benefit, in the economic analysis, associated with the implementation of the project itself.

The basic scenario, concerning what would happen in the absence of the implementation of infrastructure enhancements, was designed as follows:

- to date, some areas of Malpensa airport are subject to flooding for a return period of less than 10 years. Some key areas of the airport, such as Runway 35L, Cargo Area, Terminals T1 and T2 and the airport's internal road network, are characterised by a partial inefficiency of the drainage network, which is also connected to climate change and increased rainfall intensity. Based on the above considerations, the basic scenario assumes that two floods occur every 10 years affecting airport operations in terms of service interruptions mainly due to diverted, delayed and cancelled flights.
- SEA SpA, in 2010-11, carried out the seismic vulnerability assessment of all buildings considered "strategic" for Civil Protection purposes or "relevant" in case of collapse due to seismic events, according to the pro tempore regulations in force (2008 Italian Building Code, NTC 200). The seismic vulnerability assessment showed that the building's capacity is significantly lower than the capacity required by the Italian Building Code for a new construction. According to the results of the assessment, in the basic scenario, the seismic return period of Passenger Terminal 1 at Milan Malpensa Airport was set at 30 years. Combining these data with the considerations described above and applying the intensity ratio between two subsequent values, the impact of an earthquake for each intensity on the MMI scale was estimated in terms of the number of days of interruption to the airport services considering, for the basic scenario, the occurrence of infrastructure damage from an earthquake of MMI scale intensity equal to or greater than V.

The scenario in which the project is implemented was designed as follows:

- SEA S.p.A. planned the flood risk reduction activities starting from a hydrogeological and hydraulic analysis of the actual flood risk of the airport area. The aim of the project is to improve the airport's drainage system to increase the resilience of the infrastructure to flash flooding. In quantitative terms, the achievable goal is to reduce the frequency of flooding at the airport by increasing the return period to at least ten years. Based on this, the project scenario assumes that a flood will occur every 10 years, which will affect airport operations in terms of service interruptions, redirected and delayed flights.
- SEA S.p.A. has planned seismic risk reduction activities based on the results of seismic vulnerability assessments and further investigation and testing of structures with the goal of achieving that the capacity of the building is at least equal to that required by the Italian building code for a new construction. Consequently, the project will ensure that the seismic return period of Passenger Terminal 1 at Milan Malpensa Airport will be, in accordance with Italian requirements for new buildings, 1808 years. Combining this data with the above assumptions, the impact of an earthquake for each MMI scale intensity has been estimated in terms of the number of days of disruption to airport services considering, for the project scenario, where infrastructure damage would occur for an earthquake with an MMI scale intensity equal to or greater than VII.

From a financial perspective, incremental cash flows (i.e. based on the difference between the cash flows in the two scenarios) discounted at an appropriate discount rate (i.e. 4% as per the Guide) were used to compute the key financial indicators associated with the Project (financial NPV and financial IRR). The analysis was used to verify the financial feasibility and sustainability of the proposed Project, as well as to quantify the financing needs of the European Commission (i.e. the financing gap).

From the socio-economic point of view, an analysis was carried out to quantify the welfare changes resulting from Project implementation. In detail, reference conversion factors were used to convert the Project's financial flows into economic data. Thus, considering that observed market prices could be distorted due to various inefficiencies, shadow prices were used to fully reflect the social opportunity cost of goods and services. Once converted, the economic costs and benefits associated with the Project were discounted with a selected social discount rate (i.e. 3% as per the Guide) and key data for the socio-economic analysis were retrieved (i.e. economic NPV, economic IRR and benefit-cost ratio). Table 2 provides a summary of the variables used for the financial and socio-economic evaluation as well as the key evaluation indicators.

The following sections present a demand analysis used as input for the financial and socio-economic evaluation of the Project.

3.2. Demand analysis

Travel demand forecasting models have played an important role in transportation planning; these models support the evaluation of policies, programs, and projects that entail complex relationships between the activity and transportation systems. Since the initial four-step model structure was established, both the state of the art and the state of practice in travel demand modeling have improved significantly. However, the models are not and will never be ideal representations of the systems they represent, therefore there will always be some uncertainties in the forecasts generated by these models. Forecasting travel demand is useful in many situations, such as establishing if a suggested alternative is financially or technically possible or fulfills some benefit criterion.

In some applications, uncertainty in model forecasts may

Table 2
Summary of the variables under analysis and their assessment indicators.

Financial analysis	Socio-economic analysis
Investment costs	Investment costs
Replacement costs	Replacement costs
Net revenue	Saving travel time for passengers
	Externalities: costs of: air pollution, climate change, noise, accidents and congestion.
	Savings on operating costs related to: road passenger and freight transport services and aviation services
Evaluation Indicators	
NPV-F	NPV-E
IIR-F	IIR-E
Financing gap rate	B/C ratio

immediately translate into risks of failing to meet the objectives associated with the choice to implement or not the alternative. Because of the different risk-reward characteristics of equity and lender players, this threshold varies substantially for initiatives involving outside financing. Several prior publications detailed the uncertainty associated with estimating travel demand and suggested solutions to improve the technique. Among such suggestions is the use of rigorous quantitative risk analysis tools (Adler et al., 2014).

Therefore, for the case study under analysis, the travel demand trend was estimated. Specifically, an analysis was carried out to determine the number of passengers and cargos originated and destined to/from Milan Malpensa airport. The trend was used to estimate the financial and economic impacts of the project related to:

- the change in terms of road distances travelled (vehicle*km), calculated as the difference between the Project scenario and the Basic scenario, obtained on the basis of changes in the users' mobility behaviour originating from or travelling to Milan in case of flight diversion due to the interruption of the service at Milan Malpensa airport;
- the change in terms of air distances travelled (passenger*km or ton*km), calculated as the difference between the Project and the Basic scenario, obtained from the rerouting of flights originating from or destined to Milan Malpensa airport, following the service interruption;
- the change in passenger travel time (hours), calculated as the difference between the Project scenario and the Basic scenario, to reach or travel outside Milan in the event of a diverted, delayed or cancelled flight.

The demand analysis was based on a reference day represented by the airport's 30th annual traffic peak in 2018. The methodology adopted was divided into 4 main steps:

- analysis of the number of flights, passengers and tons coming from or going to Milan Malpensa airport;
- identification of the airports chosen as an alternative to Milan Malpensa airport following the interruption of the service;
- evaluation of the effects of the service disruption in terms of diverted, delayed and cancelled flights;
- identification of the passenger profile at Milan Malpensa airport;
- evaluation of the traffic impacts of the service interruption in terms of changes in road and air distances and travel times.

3.2.1. Flights, passengers and tons coming from or going to Milan Malpensa airport

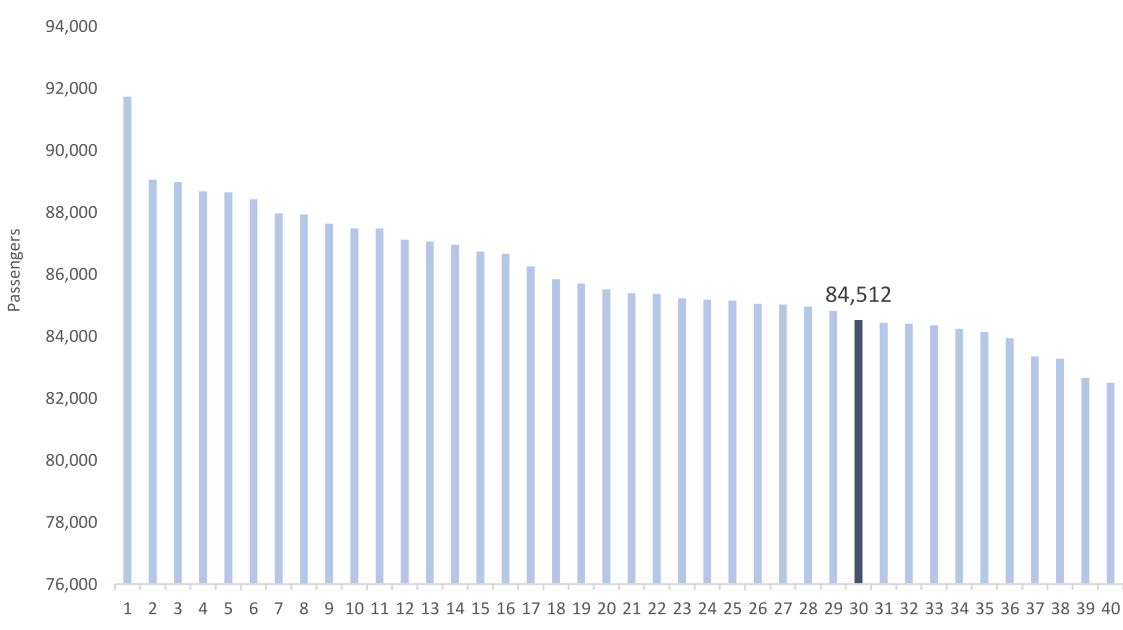
An analysis was carried out on the reference day chosen to identify the flights, both passengers and freight, originating from/going to/from Milan Malpensa airport. The results of this analysis show that the airport is respectively the origin and destination of 277 and 278 flights, for a total of 84,512 passengers and 1187 tons handled each day (see Fig. 2). These 2019 values in terms of passengers and tons handled by Milan Malpensa airport have been kept constant over the time horizon of the analysis in order not to overestimate traffic forecasts before the COVID-19 pandemic.

3.3. Selected alternative airports to Milan Malpensa airport

Passenger flights originating and destinated at Milan Malpensa airport were classified according to aircraft capacity so that, considering the runway capacity limits related to the aircraft size and weight, it was possible to assign each flight an alternative origin/destination airport. For cargo flights, on the other hand, an average aircraft category was considered.

Considering the results of the analysis, one of the following alternatives was selected for each flight diverted following a flooding or seismic event:

- for domestic passenger flights: Milan Linate, Bergamo Orio al Serio, Venice Marco Polo, Bologna Marconi, Verona Villafranca, Treviso A. Canova, Parma Airport, Turin Caselle and Genoa Cristoforo Colombo;
- for international passenger flights: Rome Fiumicino International Airport;
- for cargo flights: Rome Fiumicino International Airport.



Figs. 2. 30th annual airport traffic peak in 2018.

An alternative O/D relationship was then determined for each diverted flight in terms of kilometers travelled and travel time for each transport mode.

3.4. Effects of service interruption

As mentioned above, the project aims to mitigate both the risk of flooding and the seismic risk. To estimate the effects of a service disruption, the following assumptions were considered in the demand analysis:

- a flood event affects airport operations in terms of service disruption mainly due to diverted, delayed or cancelled flights. To estimate the impacts related to an interruption, the effects of the flooding in September 2021 were used, where the duration of the service interruption was about 3 h. The analysis showed that about 50% of passenger flights departing from Milan Malpensa airport were delayed by 3 h while the remaining 50% were cancelled. In the current demand analysis, the number of passengers for each cancelled flight was considered redirected to the next day's flight, with an average delay of 12 h. With regard to flights destined to Milan Malpensa airport, the analysis considered that all flights were diverted to the alternative airports listed above. Finally, it was considered that the service interruption had no impact on cargo flights.
- An earthquake affects airport operations in terms of service interruption for a period of time depending on the intensity of the event. The project concerns the infrastructural works to upgrade Terminal 1 for passengers at Milan Malpensa airport. Therefore, this analysis is mainly focused on the effects of a seismic event for both passengers and tonnage originating or destined at Terminal 1: all flights were considered diverted to the alternative airports listed above.

3.5. Passenger profile

The analysis was based on the passenger profile at Milan Malpensa Airport (2019) taken from SEA S.p.A. databases. The data provide information on the travel purpose and the modal split to reach Milan Malpensa airport (see Table 3).

3.6. Traffic impacts of the service interruption

Demand analysis was carried out, combining the assessment of the effect of service disruption (i.e. passengers and tons affected) with modal split considerations, in order to estimate the impacts of service disruptions on traffic in terms of:

- change in road and air distances travelled to or from Milan for both passengers and tons (expressed in vehicle*km for road transport and passenger*km or ton*km for air transport). Distances in km were calculated for each alternative O/D ratio for diverted passenger or freight flights and multiplied by the number of passengers and tons affected by the service interruption. Following a conservative approach, the change in distances travelled by road was only considered for passengers travelling to or from the Lombardy region (i.e. 77% of the total number of passengers. Source: SEA S.p.A. data).
- change in passenger travel time to or from Milan. Travel times in hours were calculated for each alternative O/D ratio for diverted passenger flights and, considering the above assumptions, for delayed or cancelled flights. The estimated values were multiplied by the number of passengers affected by the service interruption.

Table 3
Main characteristics of the passenger profile.

Passenger profile	
Reason for travel	
Deal	36%
Other reasons	64%
Modal division	
Cars	64%
Train	20%
Bus	13%
Coach	3%

Following a conservative approach, passengers travelling by train or bus were considered, which will not lead to changes in terms of train*km or bus*km, assuming constant service provision. Table 4 shows the results of the demand analysis calculated as the difference between Basic and Project scenario. The values refer to the traffic impacts of the service interruption during a representative year considered in the CBA.

4. Financial analysis

The financial analysis was based on incremental cash flows calculated as the difference between the cash flows of the Project and the Basic scenario for the entire life of the project. The methodology used is Discounted Cash Flow (DCF), which is based on estimating the Project inflows and outflows and discounting them using an appropriate discount rate. For this Project, a discount rate of 6.8% was chosen.

The following assumptions were considered in carrying out the financial analysis:

- the time horizon of the analysis was set at 22 years (between 2022 and 2043, the latter being the time limit of the SEA SpA concession for airport infrastructure management);
- the basic year for discounting flows was set at 2022;
- no account was taken of inflation, as the analysis was carried out on the basis of costs as constant values;
- A discount rate of 6.8% was selected for the financial analysis.

The main financial cash flows considered were divided into:

- investment costs: expenditure for the implementation of the Project;
- replacement costs: extraordinary maintenance costs necessary to restore the Project's infrastructure and to ensure operations after flooding or seismic events.
- net revenues: increased fees applied for the improvement of Milan Malpensa airport infrastructures during the Project implementation avoiding the loss of revenues due to the interruption of MXP airport operations in the event of an earthquake or flooding event.

4.1. Investment costs

The total investment costs were set equal to 24 million Euros incurred in the first 5 years of the time period (i.e. from 2022 to 2026) (see Table 5).

Table 4
Traffic impacts of the service interruption calculated as the difference between the project and the baseline scenario.

Traffic impacts of the service interruption	
Variation in road and air distances travelled	
Road (vehicle*km)	9.975.552
Cars	9.756.470
Bus/coach	126.580
Heavy goods vehicle (HGV)	92.502
Aircraft (aircraft*km)	155.778
Air (passenger*km)	1.742.099
Air (ton*km)	112.416
Variation in travel time	
Delays (hours)	255.732

Table 5
Project investment costs.

CAPEX (€)	2022	2023	2024	2025	2026	Total
Management and coordination activities	273.309	273.309	273.309	273.309	273.309	1.366.544
Studies and design	534.834	534.834	534.834	534.834	–	2.139.336
Improvement of the drainage system to mitigate the risk of flooding	622.468	2.489.872	2.489.872	2.489.872	1.659.915	9.752.000
Improvement of T1 terminal upgrades for mitigation of the seismic risk	2.166.943	2.166.943	2.166.943	2.166.943	1.444.629	10.112.400
Development of an intelligent monitoring system in a multi-risk framework	–	180.681	197.106	197.106	197.106	772.000

4.2. Replacement costs

Replacement costs relate to works necessary to restore the operation of infrastructure damaged as a result of a flooding or seismic event. Therefore, they do not relate to the improvement or replacement of a specific project infrastructure and will only be considered upon the occurrence of the event, whether flooding or seismic.

Total replacement costs are about €4 million for the entire time period considered. Replacement costs related to the occurrence of a flood event have been set at €300,000 as for SEA SpA’s internal estimates (i.e. effects of the flood in September 2021). Most of the costs (i.e. € 3.4 mln) will therefore be considered for restoration activities in the a seismic event.

This is justified by the fact that, if such an event occurs, the entire terminal is expected to be rebuilt. Indeed, the high seismic intensity considered for the analysis (i.e. higher than V or higher than VII on the MIM scale for the Basic and Project scenario, respectively) is expected to generate severe damage to the airport infrastructure. The key assumptions used to estimate the total replacement costs following a seismic event are reported in Table 6.

The total cost was multiplied by the probability associated with the occurrence of a seismic event in the time period considered (i.e. 22 years from 2027). The replacement costs for flooding and seismic events are provided in Table 7.

4.3. Net revenue

The net revenues correspond to the increase in fares applied to the Milan Malpensa airport operators for the improvement of their infrastructures during the implementation of the Project. According to SEA, the corresponding revenues will amount to €16.1 million for the entire time period considered.

Moreover, the total revenues lost during the interruption of operations of the Milan Malpensa airport due to flooding or seismic events should be considered. Following a conservative approach in estimating project revenues, the company’s gross operating margin was used as a reference. By construction, the gross operating margin is calculated as revenues minus variable and fixed direct costs.

In the Project scenario, isolating fixed costs was not possible. The avoided loss of revenue was calculated as the product between the hourly revenue of the Milan Malpensa airport and the differential days or hours of interruption for the flood and earthquake events, respectively. In detail, the calculation of hourly revenues of the Milan Malpensa airport was based on the following assumptions (see Table 8).

Based on the above, the total hourly revenues were calculated using a step-by-step approach: the total commercial aviation revenue was calculated for the movements of the Milan Malpensa and Linate airports for a corresponding €910 (obtained by the ratio between the EBITDA of commercial aviation in 2019 and the total movements of the two airports);

- total general aviation revenue was calculated for the movements of the Milan Malpensa and Linate airports for a consideration of €22 (obtained by calculating the ratio between the general aviation EBITDA in 2019 and the total movements of the two airports);
- the sum of the two figures above was used to compute the total commercial and general aviation revenue of the Milan Malpensa and Linate airports in the amount of €932;
- To calculate the total revenue of €465,941, the total value of revenue per movement was multiplied by the movements at Milan Malpensa Airport on a reference day;
- To calculate the hourly revenue from movements of €19,414 per hour, the total daily revenue from movements at Milan Malpensa airport was divided by 24.

Based on the above, the total loss of revenue avoided for the project was finally calculated at €15.9 million over the considered time period of 22 years. As far as flooding events are concerned, the total hourly revenues for Milan Malpensa airport movements (19,414 €/hour) were multiplied by the hours of interruption of operations (i.e. 3 h) and the number of events recorded in the project scenario (1 event every 10 years). With regard to seismic events, these were calculated as the product of the total hourly revenue and movements at Milan Malpensa airport and the differential days of interruption of operations.

The breakdown of revenues for avoided flooding and seismic events as well as for an increase of fares is reported in Table 9. It should be noted that, since a differential approach was used, avoided revenue losses were included with a positive sign in the financial analysis and were therefore considered as Project revenue.

Table 6
Assumptions for the calculation of replacement costs related to the earthquake event.

Hypothesis for seismic event	Value (€)	Source
Cost per m2 for the construction of an airport passenger terminal [€/m2].	2.000	SEA S.p. A.
Target passenger terminal [m2]	200.000	SEA S.p. A.
Total cost of rebuilding a passenger terminal [€].	400.000.000	

Table 7
Project replacement costs.

Replacement costs	Value (€)
Replacement costs for seismic events	3.420.302
Replacement costs for flood events	510.000
Total replacement cost [€]	3.930.302

Table 8
Assumptions for the calculation of hourly revenues at Milan Malpensa airport.

Element	Value (€)	Source
EBITDA (commercial aviation 2019)	268.516.000	Financial statements SEA S.p.A. 2019
EBITDA (general aviation 2019)	6.509.000	Financial statements SEA S.p.A. 2019
Annual movements for MXP airport	225.414	SEA S.p.A. Annual Report 2019
Annual movements by LIN airport	69.714	SEA S.p.A. Annual Report 2019
Movements for Malpensa airport on a reference day (30th day of the year)	~500	SEA S.p.A.

Table 9
Net revenues of the Re-MXP project.

Net revenue	Value (€)
Net revenue from tariff increase	16.171.123
Avoid loss of revenue due to earthquakes	15.842.020
Loss of revenue avoided due to flooding events	99.013
Total net revenue [€]	32.112.155

4.4. Residual value

According to the requirements of the Guidance, the residual value reflects the capacity of the residual service potential of the fixed assets included in the Project. In the Project scenario, the residual value is not negligible and different from zero. In detail, considering that the infrastructural concession to SEA S.p.A. will expire by 2043 (i.e. the end of the year of the analysis), a residual value of €7 million was calculated. This corresponds to the monetization of the impact generated by this Project after 2043.

4.5. Calculation of the financing gap

The key results of the financial analysis are summarized in Table 10, including the Project's Net Present Value, internal rate of return and financing gap rate.

As demonstrated, before receiving the requested EU contribution, the Project shows an IRR of 5.6% below the Project's interest rate (i.e. 6.8% corresponding to the WACC selected for discounting project cash flows). Therefore, without any public contribution, the development of the Project would not be sufficiently profitable.

After receiving the CEF grant, the Project's performance improves dramatically with an IRR of 10% and an NPV of about €4mln. Therefore, receiving the CEF grant could contribute to the financial strength of the Project and make it more attractive.

5. Socio-economic analysis

A socio-economic analysis was performed to assess the economic and social impacts generated by the implementation of the Project.

Through the necessary adjustment of the financial flows and the monetary quantification of the environmental and social effects generated by the Project, in fact, the socio-economic analysis allows the evaluation of the Project's economic viability in terms of interest to society. The implementation of the Project will improve the resilience of the Milano Malpensa Airport infrastructure to flooding and seismic events. In fact, the intervention will reduce the duration of the interruption related to the operation of the Milano Malpensa airport following the occurrence of an event.

As a result, road traffic will be reduced as it will no longer be necessary to switch to the road mode as an alternative means of transport, and air traffic and its emissions will decrease due to fewer diverted flights.

This modal shift, which should occur following the implementation of the investments, will result in the following economic benefits:

- savings of operating costs related to the provision of road passenger and freight transport services;
- savings of operating costs related to the provision of air services;
- reducing air pollution, the effects of climate change, noise, accidents and congestion related to road and air traffic;
- travel time savings for passengers who will not be affected by delayed, cancelled and re-routed flights as a result of the implementation of the Project.

The methodology adopted was divided into four main stages:

- setting the main assumptions;
- development of factors for converting financial values into economic values;
- identification of socio-economic costs and benefits;
- evaluation of socio-economic indicators.

5.1. Main assumptions

The socio-economic analysis is based on the following assumptions:

- a conservative approach was adopted: among the options for developing the analysis, the one that underestimates benefits and overestimates costs was preferred. This approach minimizes the risks associated with overestimating the net socio-economic benefits of the Project (i.e. the difference between socio-economic costs and benefits);
- The time period considered for the analysis was set at 22 years (i.e. between 2022 and 2043, as the time limit of the SEA SpA concession for airport infrastructure management);
- The basic year selected for the economic flows of the Project was 2022;
- A social discount rate of 3% was chosen for discounting the Project's economic cash flows;
- Insurance costs and taxation were not considered in the analysis, as they only represent a reallocation of funds between companies and insurance companies/public administration;
- costs and benefits were considered constant values.

As for the externalities, parameters were applied based on the assumption of changes in the GDP per capita at constant prices. GDP values for the years 2019–2022 were held constant to avoid considering distortion effects related to the COVID-19 pandemic.

5.2. Factors for converting financial values into economic values

To assess the socio-economic impacts of the Project, the financial flows related to its implementation were converted into economic values using selected conversion factors. In line with the methodology proposed by the Guide, conversions were implemented to cleanse the financial data of market distortions and thus compute the marginal social value of the goods included in the analysis.

Two main conversions were applied:

- current wages were converted into shadow wages;
- tax components were separated from operating costs.

The labor market is significantly distorted, as evidenced by high and persistent unemployment, downward wage rigidity, and unequal market conditions resulting in various forms of illegal and informal economy. As part of this socio-economic analysis, current labor costs were converted into shadow wages using a labor conversion factor of 0.822. Details on the calculation of the labor conversion factor are provided in Table 11.

As shown above, the labor conversion factor was calculated as a weighted average of the shadow wage conversion factor for skilled and unskilled labor. For skilled labor, the shadow wage was assumed to be equal to the market wage (i.e. conversion factor of 1.00). With regard to unskilled labor, the shadow wage was computed through the reduction

Table 10
Main results of the financial analysis.

Evaluation Indicators	Value before CEF	Value after CEF
NPV-F	−2.316.722	4.445.035
IIR-F	5.6%	10.0%
Financing gap rate	10.91%	

Table 11
Calculation of the labour cost conversion factor.

Conversion factor for labour costs		
Variable	Value	Source/Formula
A. Shadow wage conversion factor for skilled labor	1.000	Elaborations on Eurostat data
B. Shadow wage conversion factor for unskilled labor	0,643	Elaborations on data Eurostat
C. Ratio of skilled labor to total labor force	50%	Elaborations on Eurostat data
D. Labor cost conversion factor	0,822	D= (A*C) +(B*(1-C))

Source: Elaborations on Eurostat, Unemployment Statistics (2019) and ISTAT, Labor Cost Structure (2012).

of labor costs by a percentage corresponding to the share of income taxation (t) in the sector (i.e. around 28.5% according to ISTAT, 2012 estimates) and the unemployment rate (u) (i.e. 10% according to Eurostat, 2020 estimates). In detail, the formula used to estimate the conversion factor for unskilled labor was:

$$CF_{unskilled} = (1 - \mathrm{u}) \times (1 - \mathrm{t})$$

The resulting conversion factor for unskilled labor was set at 0.64. In line with the Guide, the components of direct and indirect taxation were eliminated from the market prices, as they only represent a reallocation of funds between the company and the public administration. All cost items included in the analysis were considered net of VAT.

5.3. Identification of socio-economic costs and benefits

Unlike costs (e.g. investments and replacement costs), the benefits selected for the socio-economic analysis differ from financial benefits (e.g. revenues). In fact, for the socio-economic analysis, the benefits generated for the company by the implementation of the Project were considered. They mainly refer to the reduction of operating costs for road passenger/freight services and air services, the reduction of air pollution, the effect of climate change, noise pollution, accidents and congestion, as well as the saving of travel time for passengers.

The rationale behind the calculation of socio-economic benefits was that, once the Project is implemented, the resilience of Milan Malpensa Airport's infrastructure to flooding and seismic events will be significantly improved. Therefore, the variation of the distances travelled by road and air by passenger and tons (vehicle*km, passenger*km or tons*km) as well as the variation of the travel time of passengers to reach or travel outside Milan will generate as much benefit as will be determined by comparing the Basic and Project scenarios.

5.4. Operating cost savings

One of the key benefits related to the implementation of the Project, refers to the savings generated in terms of operating costs for:

- the provision of road passenger and freight transport services;
- the provision of air services;

Operating expenses related to aviation services as well as passenger and freight road transport services are mainly related to personnel, maintenance, tyres and fuel costs.

These were calculated as the product of the following variables:

- the total number of vehicles per kilometer (road transport: cars, coaches and lorries), aircraft per kilometer (air transport) travelled in the event of flights being diverted due to the occurrence of a flood or seismic event;
- operating costs for road and air transport converted into economic values and indexed to GDP growth per capita.

Table 12 shows the operating costs and their sources used in the calculation.

The savings benefit on total operating costs amounts to approximately €90m (NPV €62m) over the entire time period considered.

5.5. Externalities

Externalities are socio-environmental effects generated on society by the implementation of the Project. Project benefits were assessed for air pollution, climate change effects, noise, accidents and congestion as a product of the following variables:

- the total number of vehicles per kilometers (road transport: cars, coaches and lorries), passengers per kilometers and tons per kilometers (air transport) travelled in the event of a flight being diverted due to the occurrence of a flood or seismic event;
- marginal costs as recommended by the 'Handbook on the External Costs of Transport - 2019′ for road and air transport indexed to real GDP growth per capita.

Table 13 shows the marginal costs used in the calculation.

For road transport, a specific analysis was conducted to estimate the effects on climate change. The emissions considered in the analysis are greenhouse gases:

- carbon dioxide (CO2);
- natural gas (CH4);
- Nitrogen monoxide (N2O).

The estimation of the different types of emissions was carried out on the basis of SINAnet-ISPRA parameters, considering the characteristics and evolution of the vehicle fleet (e.g. type of vehicle, type of fuel) and the type of road. Emissions of atmospheric pollutant gases (CH4, N2O) were converted into $_{CO2}$ equivalent through standard Global Warming Potential (GWP) parameters as recommended by the" *Intergovernmental Panel on Climate Change (IPCC)* " within the framework of the" *IPCC, 2014; Climate Change 2014: Synthesis Report* ".

The average emissions, in terms of CO 2-equivalent (g/vehicle*km), of cars, coaches and lorries, were multiplied by the estimated decreasing vehicle*km variations, determining the total annual emissions avoided as a result of the Project's implementation.

The benefits of the Project in terms of reducing greenhouse gas emissions were calculated as the product of the following variables;

- the estimated average emissions, in terms of CO2 equivalent (g/vehicle*km), for passenger cars, buses and heavy goods vehicles;
- CO2 costs as recommended by the *'Technical Guide on Climate Proofing of Infrastructure in the period 2021–2027, European Commission - 2021'* (available for the time horizon 2022 - 2050);
- the total number of vehicles per kilometers per car, bus and heavy goods vehicle travelled in the event of a flight being diverted due to the occurrence of a flood or seismic event.

Table 14 shows the benefits of externalities.

Table 12
Assumptions for the identification of the operating cost savings benefit.

Operating cost	Value	Source
Road transport costs (€/vec*km)	1.126	Road haulage for hire or reward, indicative reference values of the operating costs of the company, MIT (2021)
Road passenger cost (€/vec*km)	0,331	ACI (2017)
Aviation costs (€cent/plane*km)	1.299.269	Processing

Table 13
Marginal costs for calculating externalities.

Externalities	Value	Source
Air pollution		
Car (€cent/vec*km)	1.180	Handbook on External Costs of Transport - 2019
Bus (€cent/vehicle*km)	14,69	Handbook on the External Costs of transport - 2019
Truck (€cent/vehicle*km)	9.710	Handbook on External Costs of Transport - 2019
Air (€cent/pax*km or ton*km) *weighted average value for short, medium and long distances	0,269	Elaboration based on handbook on the External Costs of Transport - Values 2019
Climate change		
Air (€cent/pax*km or ton*km) *weighted average value for short, medium and long distances	2.422	Processing based on Handbook on the External Costs of Transport - Values 2019
Incidentality		
Car (€cent/vec*km)	6.957	Handbook on External Costs of Transport - 2019
Bus (€cent/vehicle*km)	9.167	Handbook on the External Costs of transport - 2019
Truck (€cent/vehicle*km)	26.564	Handbook on External Costs of Transport - 2019
Air (€cent/pax*km or ton*km) *weighted average value for short, medium and long distances	0,033	Processing based on Handbook on the External Costs of Transport – Values 2019
Congestion		
Car (€cent/vec*km)	5.418	Handbook on External Costs of Transport - 2019
Bus (€cent/vehicle*km)	13.974	Handbook on External Costs of Transport - 2019
Truck (€cent/vehicle*km)	8.332	Handbook on External Costs of Transport - 2019
Noise pollution		
Car (€cent/vec*km)	1.439	Handbook on External Costs of Transport - 2019
Bus (€cent/vehicle*km)	9.535	Handbook on the External Costs of transport - 2019
Truck (€cent/vehicle*km)	8.427	Handbook on External Costs of Transport - 2019
Air (€cent/pax*km or ton*km) *weighted average value for short, medium and long distances	0,229	Processing based on Handbook on the External Costs of Transport – Values 2019

Table 14
Project externalities.

Externalities	Total (€)	NPV (€)
Air pollution	2.828.666	1.934.731
Climate change	9.659.310	6.352.434
Incidentality	13.703.470	9.372.800
Congestion	10.609.382	7.256.528
Noise pollution	3.151.279	2.155.389
Total	39.952.108	27.071.882

5.6. Saving time per passenger

Among the benefits of implementing the Project there is the travel time saving for passengers who will not be affected by delayed, cancelled and re-routed flights.

The time values recommended by the 'Handbook on the External Costs of Transport - 2019′ were considered for each travel reason (e.g. business 15.00 €/pax*h, other 6.00 €/pax *h).

Considering the assumptions presented in the demand analysis, travel time savings for passengers who will not be affected by delayed, cancelled and re-routed flights were calculated as the product of the following variables:

- the change in travel time estimated as an impact of the service interruption;
- time values indexed to the growth of real GDP per capita.

The total benefit of saving travel time amounts to approximately € 38 mln (NPV 26 mln€) for the entire time horizon considered.

All the items considered in the economic analysis are shown in Table 15.

The results of the cost-benefit analysis are determined, which show that the Project will produce benefits for the company greater than the costs: i.e. the ratio between the benefits and costs is 5.53. The present value of the Project (NPV-E) is approximately 99.8 mln € and the Economic Rate of Return of the Project is 25% (see Table 16).

6. Conclusions and further perspectives

In this paper the benefits and the costs of strengthening infrastructure assets to make them more resilient has been dealt with.

The study provides an added value to the international literature in terms of examples of application of a cost-benefit analysis for providing the resilience of infrastructures. In the coming years in which the phenomenon of climate change will increase, at the national, European and global context, cost-benefit analyses relating to the resilience of infrastructures will be increasingly necessary.

This work can be considered a theoretical and practical support tool for conducting a cost-benefit analysis in the context of the resilience of transport infrastructures, respecting the directives required by the European Union for the request for access to funds. Following the results of this work, it has been demonstrated that the cost-benefit analysis tool can be also applied to the assessment of the resilience of infrastructures. Furthermore, it has been demonstrated that the European Union, through its own funds, plays a role of primary importance in the process of modernizing infrastructures.

In the specific case, through the results obtained from the financial and economic analysis of the Re-MXP project, the need to improve investments emerged, underlining the importance of the project for SEA S.p.A. and the community.

Finally, thanks to the flexibility of the model used, by making changes and having sufficient data available, it is possible to extend an analysis of this type even outside the airport infrastructures. Future research suggests the application of this methodology to other case studies which could deal with other transport and non-transport infrastructure. An example can be the application to High Speed Rail infrastructures, which are alternative transport modes to airpoprt infrastructures (Dobruszkes et al., 2022).

Author statement

FRANCESCA PAGLIARA HAS SUPERVISED THE WHOLE WORK, THE CONCEPTUALIZATION, THE METH ODOLOGY, WRITING AND EDITING.

MARCO ZINGONE HAS CONTRIBUTED TO DEVELOPMENT OF THE CONCEPTUAL FRAMEWORK AND TO THE MEASURES OF COSTS AND BENEFITS.

Table 15
Total costs and benefits considered in the economic analysis.

Socio-economic analysis (€)	VAN	Total
Residual value	3.957.074	7.361.324
Replacement costs	2.681.785	3.897.302
Externalities (Pax + Freight)	27.071.882	39.952.108
Time saving Passengers	26.118.926	38.187.086
Savings in road operation (Pax + Freight)	35.464.817	51.851.214
Aircraft Operation Savings (Pax + Freight)	26.558.689	38.830.040
Incoming Flows	**121.853.173**	**180.079.074**
CAPEX	22.018.678	23.347.282
Outflows	**22.018.678**	**23.347.282**
Net cash flows	**99.834.495**	**156.731.792**

Table 16
Main results of CBA analysis.

Evaluation Indicators	Value
NPV-E	99.834.495 €
IIR-E	25%
B/C ratio	5,53

Data availability

Data will be made available on request.

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