Sustainability Crossing the City: Developing a Sustainable Infrastructures System for Genoa Urban Center

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Abstract. Sustainable development of infrastructures is becoming more and more relevant within a European and International framework where effective connections are pivotal in terms of social and economic systems' growth.

Nevertheless, as far as urban historical, dense and concentrated areas are concerned, intervention on urban infrastructures network could represent a very challenging task. In this sense, a quite iconic case may be represented by Genoa urban center. Here, the viaduct connecting the Eastern and the Western part of the city -Sopraelevata- proves to be outdated and not able to cope efficiently with contemporary traffic flows and mobility needs. At the same time, it is perceived as a sort of urban landmark running along the former border between city and port areas, so that demolition is not welcomed by citizens; by the way, deep interventions would be needed to make it again an effective link suitable for vehicles connections.

The rationale of the Genoese project was to define a double system of sustainable infrastructures. The existing one (the Sopraelevata) was dedicated to pedestrian and bi-cycle mobility, thus creating a new panoramic view on the city and the seaside both for tourists and residents, while a new submarine tunnel crossing the gulf was to be built to support and ease vehicle flows passing city center.

Present work will focus on the methodological approach followed to define sustainability targets to be achieved in the project by the new infrastructural scheme, both for existing and new component.

Keywords: Sustainable Infrastructures · Sustainability Rating · Multi-dimensional Assessment

1 Introduction

Infrastructures' pivotal role in driving and leading territorial development strategies has been investigated for long [1]. Accessibility represent indeed one of the main competitive factors both for regions and stakeholders [2–6], and transport infrastructures represent somewhat the pre-condition making urban areas closer one to another, assuring efficient and effective relations, thus reducing real and perceived transport cost both for people and goods.

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O. Gervasi et al. (Eds.): ICCSA 2023 Workshops, LNCS 14111, pp. 489–507, 2023.
https://doi.org/10.1007/978-3-031-37126-4_32

Globalization, furthermore, making connections crucial for supply chain and individual lives which develop worldwide and going beyond traditional borders and boundaries, put transport infrastructures at the center of public debate and action [7]. Although this have already happened in the past, present boost to infrastructural development targets the need to ensure green, smart and inclusive transition towards a more sustainable transport and urban system [8].

The risk in investing in new transport infrastructures, especially when urban contexts are concerned, could be represented by the attraction of growing vehicles flows, thus hampering the need to reduce traffic and consequent polluting emissions. Nevertheless, according to the Avoid-Shift-Improve paradigm [9], being necessary to assure accessibility and effective mobility to urban areas, particular attention must be paid to the promotion of sustainability in all its three dimensions [10].

Dealing the avoiding part more with land-use planning -in this direction, boost to remote work and education due to Covid19 pandemic outbreak represented an essential tool [11], first component of this paradigm has been targeted with new approaches dealing with proximity and mixitè, 15-min city by Carlos Moreno above all [12–14].

Moreover, as far as the shift and improve part is concerned, focusing on transport and mobility planning, to balance both targets to shift urban mobility patterns to more sustainable modes that have less impact on society and environment, and to improve transport environmental performances where shift is still not possible, should be the aim of urban committed policy makers [15].

At the same time, when transport sustainability is concerned, main accent is put on reducing GHG emissions' through the use of greener technologies and the transition towards public transport and slow mobility (e.g. walking or cycling). It must be remembered as well that socio-economic aspects should be addressed.

Infrastructures' externalities proved indeed to be extremely relevant [16, 17] in terms of social inclusion, individual well-being, health and access to economic and personal growth opportunities [18]. These reasons together with the difficulties related to monetize qualitative impacts according to different users' interests and goals contributed to the strong request to assess infrastructural investments with multi-dimensional evaluation supporting and integrating traditional Cost-Benefits Analysis (CBA) [19, 20].

Present work aim is therefore to offer a potential way to approach infrastructures' sustainability referring to both existing and new interventions. This will be done through the application of two different methodologies: scenario design and learning by cases. In particular, Genoa case-study was investigated, as public debate and local administration re-cent attention and resources are focusing on the potential regeneration of an iconic urban infrastructure, the so-called Sopraelevata, which should be dedicated to pedestrian and cycle-mobility, and the simultaneous construction of a new submarine tunnel to cross more effectively the gulf.

In the next sections, the two methods that will be applied to the Genoa case study will be analyzed. The second section provides background knowledge useful for the subsequent methodological investigation. We focus on the sustainability of infrastructures following the analytical approach proposed by international systems for classifying the sustainability of new infrastructures and, finally, we highlight the link between the urban infrastructural heritage and certain declinations of green infrastructure that are of interest

to future urban planning. Following the presentation of the Genoa Overpass case study (Sect. 3), the fourth part of this paper introduces the two methods adopted to investigate the future of the case study: scenario design and learning-by-case. Finally results on potential ways to face sustainable transition of present and future infrastructural heritage will be discussed (Sect. 4).

2 Background

Our research gravitates around the concept of sustainable infrastructure and how it affects urban planning and mobility. Two main issues emerge at this juncture: sustainability assessment and the green evolution of urban infrastructure assets.

For this reason, the next two subsections deal with these aspects, in order to apply the correct method to the case study of Genoa.

2.1 Measuring and Mainstreaming Infrastructures' Sustainability

Addressing sustainability in infrastructures design procedures, has been therefore one of the main challenges of the last decades. Due to their relevance both for their potential boost to local development and accessibility and their significant externalities, overlapping with most of the UNO's Sustainable Development Goals, infrastructural projects have been targeted has one the most eligible objects to implement sustainable policies [21–23].

Attention has been paid at embedding similar considerations from the very initial steps of spatial and strategic planning [24] as well as to the labelling of construction materials and processes [25].

Together with this growing sensitivity and commitment in implementing sustainable infrastructures planning and projects, the need to develop transparent, self-evident and measurable methodologies able to convey and prove to citizens this commitment and a responsible way to invest towards sustainability and resilience of urban systems [24] led to the affirmation of quantitative tools, such as the definition of several sets of indicators, checklist and scoring methodologies [26]. Following the approach already implemented for buildings [27], several assessing methodologies were defined indeed to support and standardize the evaluation of infrastructures' sustainability through checklists and rating systems [28]. Initially, this kind of initiatives was mainly boosted by private companies and associations providing certificates and labels, according to the sustainability level achieved (e.g. Envision Protocol, CEEQUAL, BCA Green Mark). Nevertheless, when sustainability become a legally-binding pre-requisite for public investment and projects, State and public bodies began to implement specifical assessing methodologies, as well. Italian Ministry for Infrastructures and Transport, for instance, developed the Scoring Model for Sustainable Mobility and Infrastructures-SIMS, in order to enhance a multi-dimensional approach to assess and identify priorities among public investments' alternatives targeting several kinds of infrastructures.

Implementing multi-dimensional assessment to develop sustainable infrastructural network represents nowadays one of the main challenges, so that several methodologies, proxies and protocols have been implemented (e.g. Envision, SIMS…). Usually,

they offer checklist and scoring system, helping policy makers to identify priorities and more promising alternatives [29]. Most of them provide specific tools to include social, economic and environmental evaluation since the very first steps of designing process, in order to develop projects which integrate multiple dimensions intrinsically and not only to accomplish ex-post requirements.

Growing accent on quantitative and standardized approach was strongly supported as well not only to assure democratic control on public expenses of citizens, but to evidence the compliance to a more and more complex regulatory framework, as well, and for EU authorities and bodies to monitor public resources investments. This proved to represent a crucial element as far as Next Generation EU program dedicated unprecedented resources and efforts for green, smart and sustainable transition of European economy and system [30] to recover from Covid-19 pandemic related crisis.

Looking at rating systems criteria, nevertheless two issues emerge: they mainly deal with new infrastructures and they are implemented for individual project, which may be later compared through the score achieved.

Similar assumptions rarely reflect a real-life urban scenario.

As far as European cities are concerned, building new infrastructures is only one side of the green and sustainable mobility transition.

Existing infrastructural heritage needs to be innovated, when it is possible, or dedicated to alternative uses through regeneration processes, and finally demolished when other options are not available. In a circular perspective, even when new infrastructures need to be built, communities need to manage existing ones future perspective, trying to avoid unnecessary new soil consumption [31, 32].

Moreover, historical and consolidated urban areas often require integrated and complex intervention to act effectively on local transport and mobility system. Introducing new infrastructures or existing ones retrofitting and regeneration im-ply the development of multi-level and multi-dimensional scenarios [33].

Within this framework, checklist and rating systems need to be supported, enriched and implemented through the design of potential scenarios that may later be comprehensively assessed in terms of environmental, social and economic sustainability. Protocols and scoring methodologies may set the framework for the evaluation of urban infrastructure-based scenarios' sustainability as it will be shown regarding Genoa case-study.

2.2 Green Infrastructure in Urban Infrastructure Heritage

The circularity of the infrastructural heritage, the landscape value of urban infrastructures and the continuous grey-green of infrastructures are three themes that can dialogue in the sustainable redevelopment of infrastructures.

The urban landscape is the representation of the interaction between natural forces, technical and economic needs, the adaptation of space to use, cultural expressions and the needs of society. This knowledge and the symbolic bond that is generated over time represent opportunities for a more sustainable planning and management of the future urban landscape [34]. One of the prerequisites for starting a Heritage Conversion Project is that it also possesses an intrinsic value given by the link with the image of the city that

its citizens have [35]. Furthermore, in a vision of green evolution of heritage, it cannot, by its very nature, disregard its origin as grey infrastructure.

In 2013, the European Commission published the report Building a Green Infrastructure for Europe [36]; an incipit for an increasingly intensive process of investigation, study and dissemination on the topic of Green Infrastructure (GI). In fact, it has emerged that the concept of GI is increasingly widespread and consolidated especially in the urban environment [37–39]; as they are seen as a tool to facilitate adaptation to climate change [38, 40] and to design a more resilient [41] and inclusive city [42].

How to make a Mediterranean City resilient is a complicated challenge since they are complex urban organisms that have grown up around the environmental, morphological limits that have characterized their history. The temporal continuity of the built heritage is relevant in interpreting an evolution towards a resilient city [43]. Furthermore, the literature shows that the topic of GI is shared and dealt with by numerous disciplines, including urban and landscape planning, environmental management, hydrology, ecology, mobility, engineering, and the real estate and commercial sector [44–49]. As we have just seen, the scope of GIs is very wide and varied, so they are mainly described through three fundamental and non-exclusive characteristics: all natural green areas, managed and unmanaged, both in urban and rural contexts; paths and connections between different green areas; GIs provide and continue to provide multiple benefits to people [50].

This subdivision, in relation to our research, is useful because it allows us to focus on the third aspect that characterizes a GI: providing environmental and social benefits to an (urban) environment. However, when considering existing and decommissioning infrastructure assets, it is complicated to give them a Green label. In this case, variables relating to use, economic investment and valorization of the element are involved [37, 51]. Indeed, the main challenge is to be able to encourage and stimulate the formulation of a new method or a new sustainable and green approach to the redevelopment of these artefacts [52]. GI is thus presented as complementary to various spatial planning approaches that can be effectively integrated with discussions on transport, health and urban growth.

GIs are attributed a chameleon-like characteristic [53], which derives from the combination of the multiple benefits to which it is required to respond and the disciplinary declinations that promote its use. There is a grey-green continuum of thought regarding the concepts of 'infrastructure', although 'green' can be used to indicate the function or structure provided by an element, even if it is not strictly 'green' in terms of land use [54]. Therefore, the distinction between grey and green is not entirely useful, but there is a range of nuances in between, such as cycle paths, elevated linear parks, and harbour waterfront reclamation. Elements that could be classified as 'grey', but contribute to the broader functioning of green infrastructure, should be treated as part of the Green Infrastructure Network [50].

In conclusion, the role of the built infrastructure heritage still remains insufficiently explored [35]; it is necessary to understand how it can become a resource for the urban ecosystem in terms of sustainability and green footprint or whether these are unreachable goals.

3 Genoa Case-Study

Considering the context of dense and consolidated urban areas, Genoa, located in North-Western Italy may represent a particularly relevant and iconic case-study. Globally, municipality population approximately counts 580.000 in-habitants and urban fabric develops over a thin land stripe running between the mountains and the coast, which measures a 30 km width at its maximum.

Coastline shapes a quite circular gulf facing the sea in the core of Genoese urban area, where population density reaches its highest level, going beyond 10 000 inhabitants/sq.km.

Space has historically been indeed a precious and critical issue for Genoese urban development, thus causing frequent territorial conflicts.

This critical balance was made even more precarious because of the co-existence of port and civil activities within the dense and complex historical center [55].

At the beginning of 1960s, when vehicles flows began to run across the city, a new viaduct -the so-called Sopraelevata- was built in order to provide drivers with an easier and more efficient way to cross the city [56]. To minimize its impact on urban and port uses and activities, its path was designed overlapping port-city border along the gulf.

This central and strategic location made the Sopraelevata a sort of landmark for Genoese residents and visitors, a panoramic balcony to look at the city skyline facing the city while crossing its historical center.

Despite its symbolic value, during the decades its transport and functional effectiveness decreased and nowadays it became self-evident its need to be updated and re-functionalized. Its strategic location, its pivotal role for urban mobility, as well as its iconic link with Genoese local community, sparked the debate on how dealing with its future.

During the decades several alternative scenarios were provided to design new routes to cross the city center. Most direct paths were identified crossing the gulf with submarine or over-sea solutions.

Final hypothesis was defined after Morandi Bridge collapse and subsequent de-cision to compensate Genoa municipality and community with a new strategic infrastructure as a way for the motorway network licensee to somewhat repay local society of the disaster and dramatic breakdown for the city [57] (Beltrametti et al., 2018): a submarine tunnel developing under Genoa Old Port basin, connecting the Eastern and the Western endpoints of the gulf was to be designed.

This decision is in continuity with the project for the infrastructural enhancement of medium-distance traffic on the sea side promoted by the municipality of Genoa [58] The central section of Strada a Mare Guido Rossi and Lungomare Canepa has already been realised, and the extension of the axis both to the west and to the east is planned (see Fig. 1). The issue of the San Benigno infrastructural node and the continuity of the Sopraelevata or the construction of the underwater tunnel is one of the challenges to which the municipality of Genoa is trying to find a solution. Once procedures for technical design of the submarine tunnel were started, questions about its relations and overlapping function with the Sopraelevata viaduct emerge.

Being necessary to assess new infrastructure project according to the sustainability rating system (SIMS) implemented by Italian Ministry for Infrastructure and Transport,

the aim was to extend evaluation procedures from the individual project to a wider scenario including the Sopraelevata variable, as well.

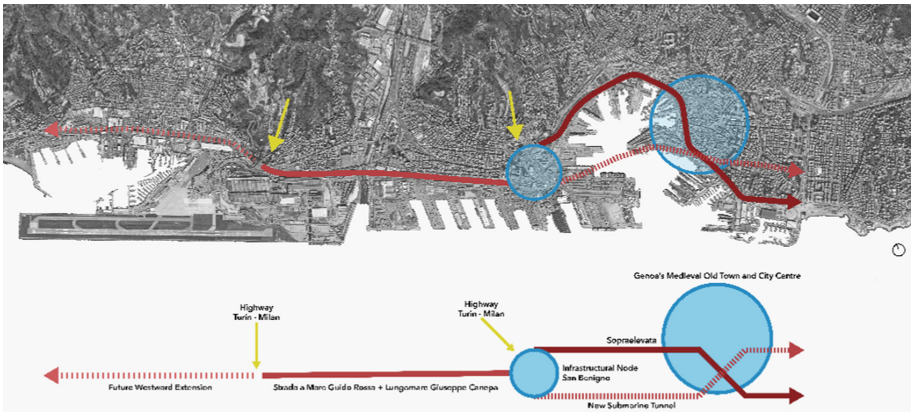

Fig. 1. Above: satellite view of Genoa with tracing of the present and future axes through the city. Below: schematic example of the same routes with relation Overpass-Submarine tunnel. Dashed lines indicate a planned and not yet realized infrastructure work.

4 Methods

The dual system methods may therefore be seen as an interesting example to implement sustainability assessment both to existing and new infrastructures. Firstly, a participated approach was brought forward to develop multiple scenarios, in order to identify most suitable use addressing sustainability and life-quality for residents and tourists. At the same time, a multi-dimensional scoring methodology provided by Italian Ministry for Infrastructures and Transports was applied to sub-marine tunnel project to include and assess environmental and social issues.

Secondly, the learning-by-case method will be used to identify which approaches are most suitable for the upgrading of the causeway. This takes place in a little-debated context in which the sustainable redevelopment of an urban infrastructure is mainly based on design experience. The aim of this activity is to develop potential further scenarios to frame re-functionalization alternatives.

Finally, the two methods of scenario design and learning-by-cases are combined to refine the results achieved.

4.1 Scenario Design for Up-Scaling Sustainability Assessment

To widen sustainability assessment approach, first necessary step was to define local infrastructural scenarios, that could constitute the reference basis to develop multi-dimensional sustainability assessment (Fig. 2):

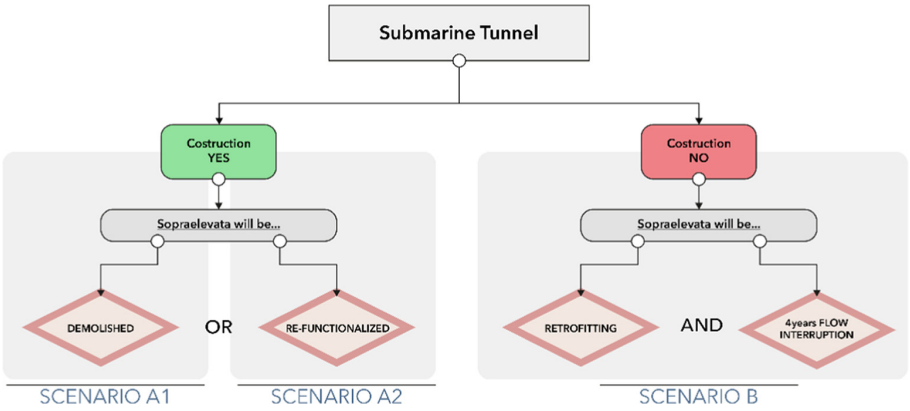

Fig. 2. Scenario's Definition.

- Submarine Tunnel construction and Sopraelevata demolition or re-functionalization. Second hypothesis includes the construction of the new tunnel, together with the prevision that the Sopraelevata will not constitute a traditional transport infrastructure any longer. This open question may hint both at its demolition or its regeneration and re-functionalization as a green linear balcony over the city, or a pedestrian or bicycle dedicated infrastructure.
- Sopraelevata maintenance, structural intervention and retrofitting. New infrastructure is not to be built, thus requiring the existing one to be up-dated and innovated to be able to carry contemporary traffic flows in a more sustainable, effective and efficient way. In this scenario, four years of construction operations are considered with consequent impacts on traffic flows changes and interruptions.

Once scenarios have been defined, they were later mainstreamed within SIMS assessment flow, being each of them evaluated according to a four-dimensions approach: (a) Financial and economic; (b) Environmental; (c) Social; (d) Institutional and governance.

Each dimension was further framed thanks to a wide range of domains and sub-indicators (Table 1), thus enabling to assess infrastructural scenarios impacts on multiple urban and community factors.

Table 1. Multi-dimensional Domains and Indicators applied to the assessment of infrastructure sustainability, as SIMS guideline.

Dimension	Domain	Indicator
a) Financial and Economic	a.1. Financial Analysis	*a.1.1. Investment Cost*
		a.1.2. Operating Costs

(*continued*)

Table 1. (*continued*)

Dimension	Domain	Indicator
	a.2. Cost-Benefit Analysis	*a.2.1. Economic Internal Rate of Return*
		a.2.2. Economic Net Present Value
	a.3. Economic Development Impacts	*a.3.1. Tourist Attraction Impacts*
b) Environmental	b.1. Six Environmental Goals Contribution-Environmental Issues	*b.1.1. Population and Human Health*
		b.1.2. Biodiversity
		b.1.3. Soil, Land-Use and Agricultural Heritage
		b.1.4. Geology and Water
		b.1.5. Air and Climate
		b.1.6. Landscape, Cultural and Material Heritage
	b.2. Six Environmental Goals Contribution-Physical Agents Issues	*b.2.1. Noise*
		b.2.2. Vibrations
		b.2.3. Non-Ionic Radiations
		b.2.4. Light Pollution
		b.2.5. Ionic Radiations
c) Social	c.1.Accessibility	*c.1.1. Average Site Accessibility*
		c.1.2. Fair and equal access to job opportunities
	c.2. Employment	*c.2.1. New construction-related employment*
	c.3 Beneficiaries	*c.3.1. Supplied Demand*
	c.4. Other Social Impacts	*c.4.1. Other social impacts-Construction Phase*
		c.4.2. Other social impacts-Operational Phase
d) Institutional and Governance	d.1. Programs and Plans Compliance	*d.1.1. Compliance to EU, National and Regional development strategies*

(*continued*)

Table 1. (*continued*)

Dimension	Domain	Indicator
		d.1.2. Compliance to EU, National and Regional urban development strategies
		d.1.2. Compliance to EU, National and Regional road infrastructures development strategies
	d.2. Stakeholders Involvement	*d.2.1. Community acceptance*

Following present scheme, scenarios could be given scores and be compared, too. Nevertheless, scenarios' setting procedure had been developed according to a tunnel-centered perspective. This is to say that first scenario was defined independently from the Sopraelevata future, whether it would be demolished or re-functionalized, while the second one, dealing with merely technical and engineering solutions, was described since the initial hypothesis were drawn.

This procedure, nevertheless, could prove to be more critical to apply to existing infrastructures, where ex-post evaluations are ineludible.

4.2 Learning by Cases for Sopraelevata Re-functionalization and Retrofitting

As seen above, the evolution of an urban infrastructure into a sustainable infrastructure is an untrodden path; all the more so when considering an evolution from grey to green infrastructure. Therefore, in order to be able to imagine a possible re-functionalization of the Sopraelevata, independently of the realization or not of the submarine tunnel, it was decided to proceed through a learning-by-cases method.

This approach is based on a search for case studies that have already dealt with this issue and a subsequent critical analysis of them. With regard to the case study of the causeway, this was done by researching sustainable redevelopment projects of urban infrastructures around the world, e.g. the High Line in New York and the Promenade Plantée in Paris; subsequently, the research was extended to projects involving new urban infrastructures in which the planners have adopted a medium- and long-term sustainable approach in all its facets: social, economic and environmental, e.g. Minimetrò in Perugia, Minhocao in Sao Paulo. This research resulted in 28 case studies to be critically compared and analyzed (see Table 2).

As can be seen from the table above, most of the interventions identified concern projects realized after the 2010s. These interventions are mainly located in the city center and only 7 of them are new developments. By critically analyzing each project, the main design tendencies used in the realization were identified. Four different design approaches emerged from the critical analysis, regardless of the boundary conditions that distinguish each case study. It should be noted that the four approaches identified are rarely exclusive to a project, but often co-exist; in these cases, the most representative

Table 2. Summary table on the 28 cases identified during the learning-by-cases method.

Project Name	City	Year	Urban Location	Project	Status
Ring Road	Amsterdam	2016	Metropolitan Area	Renovation	Study Phase
Te Ara I Whiti	Auckland	2016	Periphery	Redevelopment	Realized
Rambla de Sants	Barcelona	2016	Periphery	Renovation	Realized
Sagrera Linear Park	Barcelona	2011	Periphery	Redevelopment	Study Phase
Simone Veil Bridge	Bordeaux	2024	Periphery	New Project	Construction Phase
Riverwalk	Chicago	2016	Downtown	New Project	Realized
London Garden Bridge	London	2014	Downtown	New Project	Never Realized
Madrid Rio	Madrid	2011	Downtown	Renovation	Realized
Carnaige	Melbourne	2019	Metropolitan Area	Renovation	Realized
Underline	Miami	2015	Metropolitan Area	Renovation	Study Phase
High Line	New York	2009	Downtown	Redevelopment	Realized
Brooklyn	New York	2020	Periphery	Redevelopment	Study Phase
BQ-Park	New York	2019	Periphery	Redevelopment	Study Phase
Bjorvika Tunnel	Oslo	2010	Downtown	New Project	Realized
Prominade Plantée	Paris	1988	Downtown	Redevelopment	Realized
New Deal	Paris	2019	Metropolitan Area	Renovation	Study Phase
Minimetrò	Perugia	2008	Downtown	New Project	Realized
Reading Viaduct	Philadelphia	2018	Downtown	Redevelopment	Partly Realized
Luchtsingel	Rotterdam	2012	Downtown	New Project	Realized
Salesforce Transit Center	San Francisco	2018	Downtown	New Project	Realized
Minhocao	San Paulo	2019	Downtown	Temporary	Realized
Jardines de Pereda	Santander	2017	Downtown	Redevelopment	Realized

(*continued*)

Table 2. (*continued*)

Project Name	City	Year	Urban Location	Project	Status
Seoullo 7017	Seoul	2017	Downtown	Redevelopment	Realized
Cheonggye	Seoul	2005	Downtown	Redevelopment	Realized
Xuhui Park	Shanghai	2020	Periphery	Redevelopment	Realized
Goods Line	Sydney	2015	Downtown	Redevelopment	Realized
Bentway	Toronto	2018	Downtown	Redevelopment	Realized
A8erna	Zaanstadt	2003	Downtown	Redevelopment	Realized

approach has been attributed to the reference case. Each project approach has been named according to its characteristics:

- Greenery: This category includes those types of interventions that are related to climate resilience, that include green strategies for adaptation and response to climate change such as: biodiversity protection, environmental regeneration and connectivity, e.g. Xuhui Park in Shanghai and Madrid Rio in Madrid. This reference to the benefits of GI is also reflected in the green regeneration projects of grey urban infrastructure, e.g. the High Line in New York that transforms an industrial railway through Manhattan into a human-scale linear park. The term green regeneration refers to a series of interventions of urban integration of the existing building stock with urban greenery.
- Up and Down: is a design theme that enhances the development on different levels and in full respect of the existing infrastructure, two dimensions are defined on a spatial level: the covering of the infrastructure and the urban valorization of the spaces underneath the existing infrastructure. The covering has the dual purpose of an aesthetic value on an element of low quality, e.g. Rambla de Sants in Barcelona, and as a tool through which to solve certain problems that inhibit the proper use of an infrastructure, e.g. protection from the effects of flooding in Underline in Miami. The design of Underline spaces focuses on giving new quality uses to low-value urban spaces, e.g. a park in Bentway in Toronto or a new square in Zaanstadt.
- Junction: The theme of connections is closely linked to functionality, the common need to connect different places within the urban context and also the re-evaluation of the areas that are put in relation, providing new opportunities for use. As in the case of Soullo 7017, in which an old motorway viaduct is converted into a pedestrian park and used as a link between the two parts of the city separated by the railway It is an essential aspect of making the city accessible and liveable, through the creation of continuous paths in harmony and coherence with the infrastructure and the urban context. The intrinsic link between the infrastructure and the city is maintained, but it is given a new type of user, e.g. the new design for Brooklyn Bridge.
- Smart Mobility: All cases focusing on new forms of mobility have been included in this project approach. This vision can be declined either through the realization of new infrastructures that do not involve the private vehicle and guarantee easy mobility through the city, e.g. Minimetrò in Perugia; or through projects that imagine

a revolution of mobility within large urban centers and capable of changing their forms and spaces, e.g. New Ring Road in Amsterdam and New Deal in Paris. Finally, we also highlight cases of projects aimed at enhancing soft mobility on a human scale, such as the conversion of a motorway junction surrounding downtown Auckland, New Zealand, into a cycle path (Te Ara i Withi), or the temporary pedestrianization of the Minhocao in Sao Pauolo, Brazil, which on weekends becomes an urban park for family entertainment.

5 Results and Discussion

The last step was to cross-reference the two methods used: scenario design and learning-by-cases. For each of the three scenarios identified: construction of the submarine tunnel and demolition of the elevated causeway (A1), construction of the tunnel and redevelopment of the elevated causeway (A2) and redevelopment of the elevated causeway only (B); a degree of affinity is attributed to the project line of the identified case studies (see Fig. 3).

This solution is useful to understand the commonalities that emerge from the application of two opposing methodologies, but which share the starting point and the final objective, the design of a sustainable infrastructure. In fact, the first method is based on the validation of a standardized and recognized procedure with the active involvement of the citizens themselves who will benefit from the infrastructure. The second method, on the other hand, is useful in defining a hypothetical imaginary on which to build a win-win and shareable design process with the community, in order to initiate a path of active design involvement.

In different disciplinary circles, the use of a learning by-case methodology, in which the confrontation and analysis of different case studies is required, is now a recognized and validated procedure [59]; moreover, basic driving principles for future project development are identified. In this paper, the qualitative assessment adopted made it possible to define four potentially applicable project scenarios that do not depend on the characteristics of the assets to be reconverted but rather rely on the political, governance will and actions that will be in a position to adopt them. The four design approaches identified from the analysis of the 28 projects can be traced back to four reference domains for sustainable urban planning of a Smart City: Greenery to Green Planning; Junction to Accessibility; Smart Mobility to Mobility; and Up-and-Down to Strategic Urban Spatial Planning. Indeed, the combined effect of driving forces such as accessibility, urbanization, globalization and impact is different in each period and able to influence the pace of change as well as people's perception of the landscape [34]. Instead, using scenario design in the urban environment allows one to analyze the future outcomes of decisions that are made in the present, in order to identify the most effective option [60] and able to coordinate the simultaneous presence of multiple surrounds in a decision-making process involving numerous random variables [61, 62].

As far as two previous methodologies' intersection is concerned, some considerations need to be drawn. Approximately one out of four considered case-studies (27%) proves to be not-suitable for the application of the approach provided. On the other hand, more than 46% of them appears to fit in.



Fig. 3. Image cross-referencing the results of the Scenario Design methodology with those of Learning-by-Cases in assessing the applicability of each in respect of the case study. Green: approach possible; Yellow: approach to be evaluated; Red: approach not applicable. Each case study was given a design approach as shown in the figure. (Color figure online)

Major criticalities concern Up-and-Down approach, despite similar percentage of non-suitable cases can be traced within the four considered domains, while higher shares of "green lights" can be found among Smart Mobility and Greenery domains.

6 Conclusions

Present contribution focuses indeed on potential benefits descending from the application of a double methodology based on Scenario-design and Learning-by-Cases approach to the evaluation of new-borne and existing infrastructures' sustainability.

From the intersection of the two methods, a new process is identified, through the definition of future scenarios that can concretize visions for the city's future and, consequently, allows for greater citizen involvement and participation in the city's decision-making process. The design of a sustainable infrastructure expressly requires a participatory process of involvement of various territorial stakeholders, also external to the work. A technical, quantitative approach should be therefore integrated with a qualitative approach that can foreshadow the future vision also for those who are not among experts in this specifical field [60, 63]. Evidently, this can also be done through the adoption of reference case studies that can ensure greater involvement in the public debate, thus allowing local stakeholders to evaluate also surrounding context elements that may help sustainability assessment and evaluation.

Significant challenges will be represented by the need of standardization and transferability of the methodology provided, both in the scenario definition step as well as in terms of considered urban domains framing reference case-studies.

Extending assessment perimeter and test-bed applications would therefore constitute a further validation for this methodology as far as new infrastructures insertion within consolidated urban fabrics and outdated infrastructures re-use and sustainable regeneration are concerned.

It is therefore clear that reaching sustainability goals as well as coping with Climate Change challenges will therefore require to act both intensively and diffusely within urban layered settlements and boundaries. In this direction, proposed methodology would play an extremely pivotal role in terms of supporting indicator-based and scoring methodologies implementation within complex, dense and ramified infrastructural networks, that uneasily could be included and mainstreamed into quantitative and synthetic assessment procedure, thus implying a more holistic approach towards integrated evaluation.

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