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Urban Environment and Nature. A Methodological Proposal for Spaces' Reconnection in an Ecosystem Function

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Abstract: Our main objective is to highlight the profound disconnect between natural and anthropic elements within urban areas, with particular reference to the morpho-functional dimensions of the urban and territorial pattern. Heterogeneity in the elements underpinning relations in urban environments, absent governing principles, predisposes to conditions of widespread dysfunction and inefficiency in the modalities of anthropic utilization of the various contexts. As a result, the functions inherent to ecological and natural networks tend to be undermined, negatively impacting the environment. To this end, this paper proposes the adoption of ecoducts, on the one hand as a means to support planning and a measure aimed at reactivating the complex functions typical of urban environments and, on the other hand, as a two-way correlation between anthropic and ecological interactions at the territorial scale. Finally, the analysis of an Italian case study will highlight the potential of such instruments in terms of creating an integrated *eco-systemic service*, capable of significantly contributing to long-term improvement in the quality of life of *urban systems*.

Keywords: natural elements; urban environment; *ecoduct*; functional connectivity; ecosystem service; quality of life

1. Introduction

Nowadays, disorganized natural elements promiscuously coexist with anthropic components that are inhomogeneous and environmentally burdensome. In aggregate, these factors compound an urban fabric whose pattern is characterized by a deep lack of connectivity among spaces, regardless of the scale of analysis or design. What emerges is a picture of an urban texture, both diffuse and dispersed, that appears increasingly fragmented and sometimes incapable of utilizing its morpho-functional matrix to activate and adequately support its purposes regarding the quantitative and qualitative utilization of the various spaces.

Such a state of affairs hinders a more befitting relationship between natural and anthropic elements, while creating functional distortions and negatively impacting the environment at the territorial scale. With regard to the use of spaces in the context of land-use planning, quantitative demands are increasingly at odds with current developmental and improvement objectives, when measured in terms of quality of life.

With its constant and rapid transformations, the urban environment tends to *forget* the role and value of its many elemental parts. These concur in the *construction*, *perception* and *enjoyment* of the landscape, being as complex in terms of the host of characteristics it embodies, as it is rich in resources. This mainly refers to the conceptual and theoretical approaches of Landscape Ecology, which studies

the characteristics of distribution, form and function of natural and human ecosystems in order to understand structure, process and meaning. In this regard, the International Association for Landscape Ecology (IALE) defines landscape ecology as a discipline that deals with the study of spatial variation in landscape at a variety of scales. In this scenario, "the complexity of biological life forms entails an incomparable capacity for co-evolution that binds the different species to their environments, yet simultaneously taking cognizance of their relationship to the multiple pathways of mankind, civilization and territories is crucial nonetheless" [1].

Taken as a *complex system* of natural and human *eco-systems*, in which full integration is realized amongst human activities, natural elements and events, across mutually compatible spatial-temporal scales, the landscape becomes the most suitable analytical dimension at which to test the functionality of the different components operating in the territory.

The *contamination* taking place between rural and urban is now an integral part of the connective tissue of the urban habitat, in which elements of naturalness coexist with the lack of precise and rational governing principles. Such a deeply fractured state of urban systems causes a number of negative effects: the interruption of ecological and natural networks' functions; the inefficiency in the anthropic utilization of spaces; scarce improvement in the quality of contexts; reduced mobility and management of fluxes; a state of environmental neglect and degradation resulting in significant reduction in levels of quality of life in urban areas; alienation from both socialization practices and participation in the governance of the territory on the part of community residents.

The *image of the city* is construed as a multifunctional *system of networks*, which are often heterogeneous, discontinuous, drawn haphazardly, either too thick or too thin, where the diversity of forms underlies its functional disorganization, resulting in tensions and conflicts in terms of environmental compatibility [2,3].

Given the above considerations, it behooves us to identify interventions able to restore and enhance functionality to the territorial structure, while improving the effectiveness of planning tools via urban design interventions with detail to scale. To this end, this paper proposes utilizing ecoducts as a support means for urban planning, deemed capable of favoring the re-establishment of functional ecological and anthropic relationships at the territorial scale in urban areas. As an intervention of novel design and a rebuilding of the peri-urban landscape, the ecoduct thus assumes the crucial role of privileged link between the autochthonous network of green infrastructure and the multi-level development structures of the urban pattern.

The case study analyzed herein proposes the adoption of the instrument applied to the design a micro-area regarding the urban pattern of the city of Trieste, namely the St. Giovanni park, in order to highlight its potential for providing integrated *ecosystem services* that contribute to significantly enhancing the quality of life of the local *urban system* over the long term.

The evaluation of the effects following the introduction of the ecoduct was accomplished by way of SWOT Analysis using an open-ended questionnaire, comparing the relational structure within the context under study at *ex ante* and *ex post* conditions with respect to the implementation of the project, so as to highlight its contribution in terms of enhancing the functional efficiency of the area as a whole.

2. Materials and Methods

The theoretical underpinnings necessary to comprehend the case study analyzed consist in the recognition of the fundamental role played by biological or ecological corridors as connecting routes between urban and natural tissues. These, in fact, play an important role in linking the *core areas* (*i.e.*, *biodiversity reservoirs* or *nodal areas*), which constitute the structural basis of ecological networks and have the characteristic of being necessary for the conservation of high-biodiversity populations. Thus, these connecting corridors ensure the workings of ecological dynamics, which constantly regenerate *core areas* and support the function of conserving biodiversity.

The continuous deterioration of these ecological networks and the ensuing dysfunction in the safety nets of ecological protection become the obligatory frame of reference for the design of urban

and natural spaces in the context of contemporary urbanism. The significant fragmentation of natural areas, generally due to the presence of infrastructure, determines numerous negative impacts on urban ecosystems. As regards fauna, the adverse effects consist in the disruption of ecological corridors, habitat fragmentation and impaired dispersion or migration capacity, possibly resulting in extinction of isolated populations.

No less troublesomeness are the shortcomings of the urban component. In fact, what emerges most strikingly is the ineffectiveness in providing benefit for humans from these fragments and the limited ability to draw advantages from the context, on the whole, which also contributes, with time, to the alienation the resident population and the restricted mobility and inefficiency in regulating flows.

The net results are a significant deterioration of the environment in general and an obvious depreciation in terms of quality of life in urban areas, in addition to growing concerns regards the consequences for socialization and participation in the management of the territorial pattern itself. Re-establishing functional connectivity of these sensitive areas thus appears crucial, through effective land-use planning geared to reinforcing interrelationships among public, natural and semi-natural spaces. Such restoration of connectivity combines the purely physical facets of the design process with the recovery of those features regarding identity and defined roles.

Examples related to this aspects include the crab bridge re-establishing connectivity on Christmas Island in Australia where an overpass was erected specifically designed to assure safe migration of the native land crab species across the island; the Banff National Park in Canada which has a native vegetation cover to accommodate the needs of the park's wildlife species and the Italian city of Pavia next to Vernavola park, which has a dual function related to restoring both ecological and urban connectivity. Fragmentation of the urban structure is mitigated precisely by employing elements of flora and fauna naturalness so as to weave a mesh out of their routes of mobility and refuge habitats within the territory, with the aim of creating new, interactive relational scenarios.

Under these conditions, whereby natural and anthropogenic elements coexist in a state of tenuous connectivity, more than mere restoration at the margins of habitats, which simply overcomes barriers physically, a series of detailed interventions must also be envisioned so as to allow the re-establishment of morpho-functional connectivity within the reference context, but also to rein in invasive and poorly functional naturalness features. This set of adaptations can be termed *ecoduct system* (or *ecoduct-based system*).

The case study under analysis is located in the city of Trieste, in Northeastern Italy. When viewed at the territorial scale, the target area consists in an urban zone wedged between two natural elements, the sea and the Karst plateau (Figure 1).

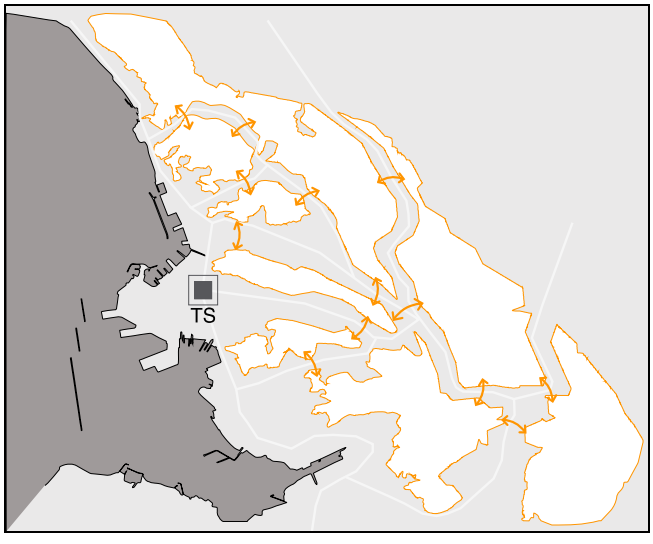

Figure 1. Graphic representation of the macro-area.

The latter component is an utter treasure for the city, a natural embrace spanning 40 km, which is a unique array of extraordinary habitats, featuring, in its midst, a luxuriant ecological blend of continental and Mediterranean wildlife species, combined with a vibrant scenery of landscapes of widely acknowledged appeal.

In the uppermost lowland zone near the city, about 200–500 m above sea level landscape is characterized by limestone and flysch soils and it is possible to find a rich, lush brushwood creating habitats of high ecological value.

To this complex system of heterogeneous elements, we must add issues of critical urgency generated over time by the sprawl of housing and infrastructure. The haphazard development of the different connecting components throughout the territory manifests, in particular, with the appearance of deep lacerations in the network of wildlife corridors that enable and support the structure and function of biodiversity within the territorial framework.

Re-establishing functional connectivity to a territorial system and its relationships entails pinpointing a strategic location to position the ecoduct structure, so as to maximize the functional efficiency of the intervention. In the case study analyzed we identified, within an urban park, a potential ecological corridor lacking connectivity which could serve as a link between the city and the components of naturalness. The close proximity of the site to the city center offered the possibility of generating, upon completion, a genuine connection network between city and nature.

An analysis of the orography of the area permitted employing the ecoduct so as to favor restoration of the greenbelt, with the aim of re-establishing morpho-functional connectivity among the elements of natural biodiversity of the urban landscape, while optimizing the utilization needs of the different categories of users, by integrating the project's structures with the territory itself (Figure 2).

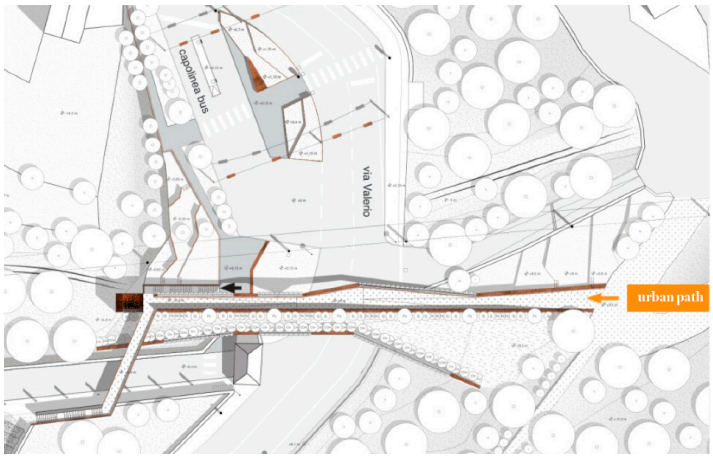

Figure 2. Graphic representation of the study area.

For the fauna, this operational choice determines the creation of new modes of perception, interpretation and use of space, in terms of new habitat settlement and mobility. For the anthropogenic component, the design solution contributes to the reactivation of the pathways through the park and those linking the park itself to the external urban system.

In general terms, besides overcoming infrastructural barriers, an ecoduct is only as effective as the *system* of precise measures included in both movement corridors. Specifically, in the ecological corridor, it is crucial to identify the different fauna and plant species to integrate into the protected area to be connected, as well as erecting a sufficiently high dividing wall at different levels, physically separating the natural corridors from footpaths, so as to preclude human disturbance to animals. The funnel-shaped design, *i.e.*, greater width at either entrance, rich in native vegetation and suitable refuges, aims to facilitate the entry of animals. The passageways to urban routes are designed to maximize multidirectional anthropogenic accessibility, both externally and within the park area.

This refers to bird species, squirrels, moderate-sized fauna and certain types of insects; medium size shrubs as shelter for birds and to provide a sense of continuity with the foliage of marginal trees; ledges at a medium height for squirrels; a low blanket of central vegetation for moderate-sized fauna and a lateral strip of smooth, artificial material as a support surface for insects' mobility and flow in different directions.

In this way, the correct functioning of the ecoduct helps restore the natural balance to the area by reactivating the prey-predator relationship.

No less regard was reserved to the role of the urban route with the introduction of design features apt to enhance the perception of its architectural qualities from within and without. From the inside, the intent was to create a sort of "outdoor room" that would frame the natural area's restored connectivity in functional terms, that is, of increased usability. From the outside, it seeks to accentuate the perception of the state of repose in contrast to the bustling motion due to the presence of the infrastructure. The contraction of the observer's cone of view while transiting the infrastructure at the maximum allowed speed of 50 km/h required, on the fringes, the use of vertical vegetation that maintains the perception of a sense of natural continuity to the slope and topography of the landscape (Figures 3–6).

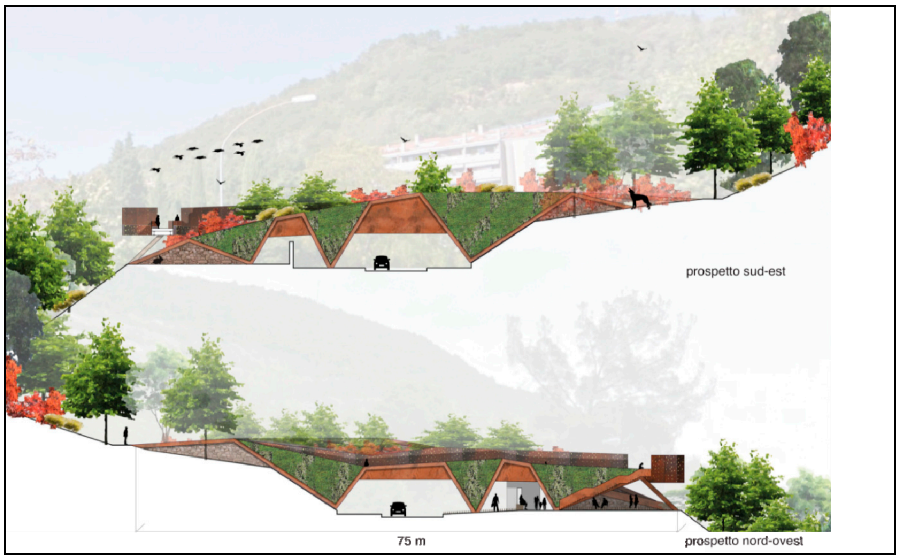

Figure 3. Perspective sections of ecoduct project.

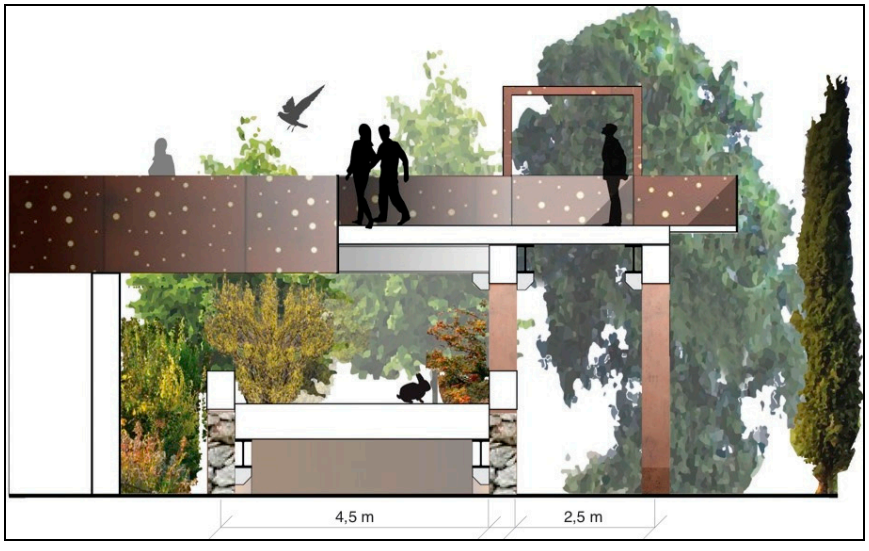

Figure 4. Pedestrian connecting footbridge (4.5 m).

Figure 5. Anthropic connection route embedded in appealing natural setting.

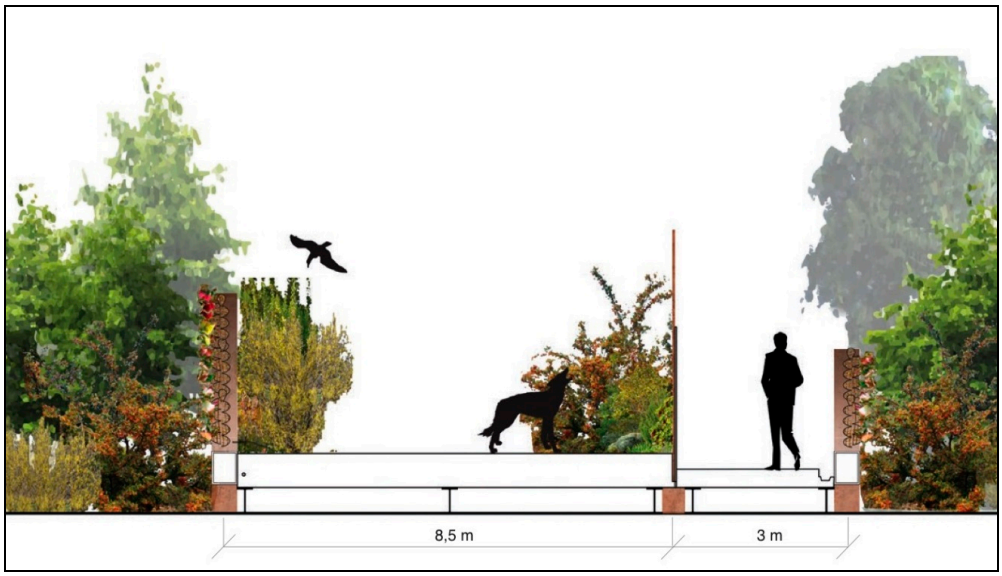

Figure 6. Relation between natural elements and anthropic presence.

The vegetation on the structure, being crucial, justifies and strengthens the choices adopted and was designed to guide target species to the area itself. For this reason, particular attention went into the selection of the native species to be included. In particular, the choice fell on various berry- and flower-producing plants with fauna-attracting qualities.

At this point, the functional design of the *margins* appears paramount, in order to take into account the re-establishment of the relationships between the urban and natural components of the landscape. The term margins is used to refer to entrances, public waiting areas and those for visitors, including linking areas providing access to means of public transport external to the study area. The reference here is to the realization of architectural elements and fittings able to satisfy a dual function, *i.e.*, urban and fauna. In particular, the case study focused on the public transport waiting area, adjacent to the ecoduct, between the infrastructure and the greenbelt to be connected (Figure 7).

Figure 7. Public transit waiting area at the margin of the ecological corridor of the park.

The idea of the project stemmed from the choice to separate this space from the infrastructure of the main extra-urban road, by landscaping the terrain, in particular through terracing. The latter in fact intends to accentuate the topography, while serving as a noise and sight barrier.

So that the *earth moving* could also serve to provide refuge for fauna the preliminary notion of using dry stone walling, for the terraces facing south, was fine-tuned in the sense of embedding honeycomb structures with cells of various sizes to attract a variety of wildlife species. On the other hand, visitors can enjoy a greater sense of privacy during their outdoor leisure activities thanks to panels 2.5 m high. In addition, the latter are equipped on one side with Wi-Fi internet access and charging points for electronic devices, whereas on the opposite side, features of appeal for avifauna and bats consist in the presence of nesting niches and bat boxes mounted at their uppermost extremities.

Finally, in line with study findings and projects for public spaces of American urbanist William H. Whyte [4], we opted to modulate the offer of space and amenities allowing users to "customize" them as a way of "taking ownership" of the public space, through their variegated, random and distinctive personal interaction, providing different options with moveable seating that can be arranged in multifunctional modes, such as work or relaxation area or as a space to enjoy an outdoor meal (Figure 8).

Figure 8. Diversified urban spaces' use.

3. Results and Discussion

Following the introduction of the design specifics, requisite for the ecoduct's realization, ensuing assessments of how the project plays out are made possible, both regarding the operative modes of the re-utilization of the area and its functional links to the surrounding environment. At this point, broadening our perspective to the territorial scale, legitimate questions may be addressed concerning the benefits accruing from the implementation of the ecoduct system, in terms of structural quality and usability.

At first analysis, it is possible to identify functioning ecosystem units that, besides guaranteeing stable re-establishment and protection of ecological corridors, on the one hand contribute to monitoring and managing the impacts resulting in environmental degradation, which, in turn, favor the loss of biodiversity, driven by the effects of climate change and pollution. On the other hand, the benefits are in terms of reactivation of the modalities of human utilization of requalified man-made urban spaces, with the creation of genuine eco-systemic services [5,6] whose nature and dynamic dimension are inter-temporal (*cf. Millennium Ecosystem Assessment*, *MA*, *Global Assessment Reports*).

In fact, it is well known that habitat fragmentation contributes, firstly, to the degradation of such services and, secondly, to worsening health by reducing the quality of environmental resources with declining well-being for local residents. Nevertheless, methods for calculating costs and benefits of ecosystem services have yet to be fully defined, rendering qualitative or quantitative comparisons

to regular services to the community challenging. Up to 2008, estimates of global annual losses in ecosystem services amounted to 50 billion euros, with cost projections, in terms of loss of biodiversity worldwide, in the order of 7% of world GDP by 2050 [7–9].

Combined with sensible environmental and landscape management, proper planning is able, over time, to ensure added value to the city and its environment in economic, ecological, historical, cultural, social, educational, recreational and aesthetic terms, considered within a general conceptual framework capable of inspiring interrelationships between man and nature, interconnecting their relative services in a dynamic dimension of the image of the city, spanning from past to contemporary [10–12].

Ecosystem services equate to ecosystem functions that prove directly useful to humans. With the project, aimed at re-establishing ecological connectivity, two different types of ecosystem services are specifically addressed, under the respective category headings of supporting and regulating ecosystem functions. The former provides services that help to support habits and provide new ones and that facilitate the soil formation processes as well as the nutrient and water cycles, whereas the latter regulates pollination, disease control, the influence of water and atmosphere, soil erosion, mitigation of invasive species, as well as waste treatment and assimilation.

The progressive fragmentation of the urban texture, determined by an inharmonious network of infrastructure, functionally undermines the ecological network that regulates the natural equilibrium within urban systems [13], also preventing the overgrowth and/or prevalence of infesting flora. Together with the interference to human socialization practices, due to diminished anthropic use of the urban territory, the bottom line is the creation of environments often lacking significance and identity, *i.e.*, non-places, suspended in a sort of structural and functional limbo, representing potential breeding grounds for untoward and random human activity.

In this sense, the choice of micro interventions relative to the ecoduct project aims to restore the profound bond between human presence and nature at the urban level, seeking a new environmental equilibrium, whereby novel modalities of rational and sustainable urban use serve to curb restoration and environmental protection costs, thus reducing the need for interventions to mitigate and compensate for environmental degradation, while pursuing the goals of enhancing the quality of urban life.

In operational terms, the effectiveness of the ecoduct was assessed by comparing the morpho-functional conditions of the study area, *ex ante* and *ex post* the introduction of the project measure, using the strategic properties of comparative evaluation offered by the Strengths, Weaknesses, Opportunities and Threats Analysis (SWOT), applied here in corresponding sections in an open-ended format [14].

In detail, in the *ex ante* evaluation phase, the SWOT analysis helps to hone the exploration of the context, more precisely identifying the components of interest, elucidating their nature, origin, role and possible degree of interdependence in creating the condition(s) of being crucial and/or detrimental. This advances the investigation and the identification of strategies, also permitting to better target the plan(s) and/or programed intervention(s) in light of the desired objectives.

In the interim, thereby still underway, this method affords decision makers considerable degrees of operational flexibility, allowing them to monitor and verify, as contextual changes evolve, whether the lines of conduct pursued and adopted are effectively in line with and relevant to the objectives, permitting timely alters, refinements and/or corrections to the instruments employed, as needed. Finally, in the *ex post* phase, achievements can be assessed in context and evaluated more rigorously.

The key factors taken into account through SWOT Analysis revealed the following types of relations: opportunities-strengths, like the development of new methodologies able to mitigate negative aspects and the exploitation of strengths, so as to take advantage of opportunities; weakness-opportunities, elimination of crucial limitations and subsequent exploitation of opportunities; threats-strengths, enhancement of strengths as a defense measure so as to neutralize internal and external threats to the system.

During the *ex ante* evaluation, or rather in the absence of due consideration of the importance of eco-system services accruing from the introduction of the ecoduct, SWOT Analysis identified the relations between strengths, weaknesses, opportunities and threats to the system, with the classical graphical representation (Table 1).

Table 1. *Ex ante* SWOT analysis.

Strenghts	Weaknesses
• site location • co-existence of diffuse and specific natural and anthropic elements • stable and consolidated road system • presence of historical-cultural and symbolic attractions	• lack of ecological connectivity • loss of identity of peri-urban areas • environmental degradation • fractured structure and functionality of ecologic network • environmental restoration and conservation costs
Opportunities	**Threats**
• recovery of the historical-cultural and symbolic value of the place(s) (place of memory) • re-establishing-morpho-functional connectivity to natural, semi-natural and anthropic elements • conservation and enhancement of the landscape features • activation of new efficient and effective modalities of stable and dedicated anthropic utilization	• degradation of complex ecosystem • loss of plant, animal and anthropic biodiversity • decreasing quality of urban life • depletion of stock of natural, semi-natural and anthropic resources • de-contextualization of the area landscape and urban degradation

The reiteration of the SWOT Analysis in the *ex post* evaluation survey, following the implementation of the project, with the adjunct of opportune micro-interventions shows the positioning of the ecoduct in the opportunities section, as a tool to enhance the environmental system, also conducive to the functional re-composition of the man-made space (Figure 9). The comparison between the two situations clearly shows the effects produced by the project: the substantial reinforcement of the positive factors, strengths and opportunities, combined with a moderate decrease in, and greater control over, weaknesses and external threats.

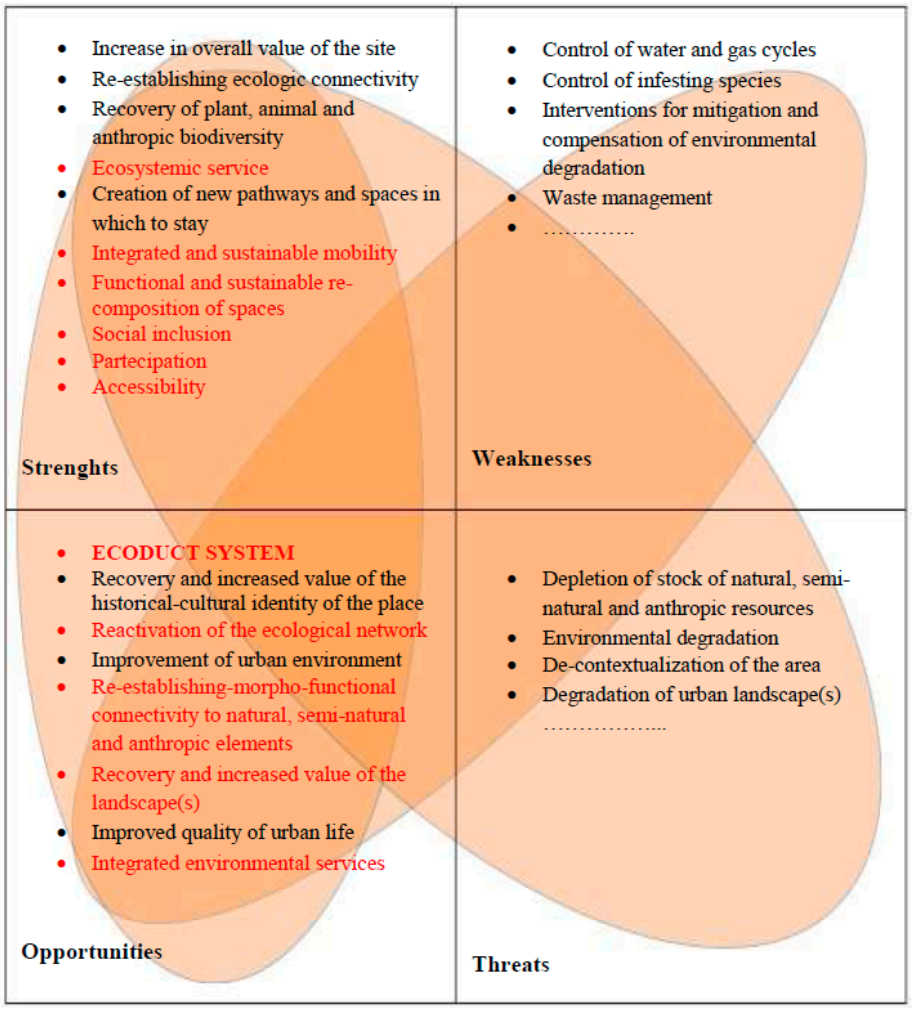

Figure 9. *Ex post* SWOT analysis.

4. Conclusions

The extraordinary geo-morphological, environmental, historical and cultural specificity of the city of Trieste, taken as our study area of reference, is one of the most significant factors in the sustainability analysis herein conducted. The presence of complex ecosystem units, of high ecological value that characterize its urban reality, enhances its potential in terms of creating a system of ecosystem services aimed at the reactivation of the relations between man and nature in urban areas, possibly improving the overall quality of life [15].

The expected benefits from the reactivation of eco-systemic services are primarily oriented towards the consolidation of the structural and functional fracture between inhomogeneous natural and man-made components, unevenly spread throughout the urban pattern. In fact, the double-edged sword of urban expansion, if, on the one hand, affords denizens a certain degree of protection from unexpected uprisings of nature, on the other, it limits their freedom of movement and contact.

With this prospect in mind, the proposed measure, that is the ecoduct, with the adjunct of timely *ad hoc* micro interventions, appears capable of achieving the tasks of re-establishing functional connectivity to margin zones and consolidating the natural and man-made landscape, all the more in a perspective of sustainability. By so doing, it has the potential to: reintegrate into the urban fabric peri-urban areas that otherwise risk isolation; defend the intrinsic historical value and promote the considerate use of urban areas; ward off the threat of loss of identity.

A passageway to sustainability and widespread accessibility is thus already laid out, one that *re-educates* the city to novel modalities of rational, sustainable, albeit short-lived, utilization of spaces, as places for action and contact, promoting occasions for encounters, fostering active participation and social inclusion [16].

The result is a new framework of the city, one of a *new urbanity*, which exploits modern technology, tools and solutions, such as the ecoduct, as in the case in point, to favor the regeneration of the urban tissue so as to create resilient cities, in which the dynamic role of environmental services effectively contributes to improving denizens' quality of life and urban living, played out in a complex setting of places and spaces.

The *representation* of the perceived and lived city thus becomes a dynamic set of reticular-structured interventions, which follows, orders and shapes the diversification of forms of enjoyment in time and space with regard to the evolution of the functional relationships between components of natural and human pressure in the urban environment [17].

Thus it appears essential, in this vision, that any endeavor, regarding analyses or urban design projects, begin with state-of-the-art, unbiased and alert planning able to interpret, via select design interventions, but first to discern the necessities for involvement and enjoyment on behalf of perceptive and multifaceted urban denizens, resilient in their quest for plausible trade-offs between the need for built space(s) and the culture of the environment [10].

In conclusion, it appears necessary to further the analysis and deepen the understanding of the issues, both from the theoretical and the methodological perspectives, so as to better elucidate the evaluation model(s) and the qualitative-quantitative indicators suited to assess the contribution of eco-systemic services, represented by the availability of environmental resources and services to the city, in an integrated and intertemporal dimension of sustainability.

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