Examining the opportunities for nature-based solutions at the Municipality of Piraeus

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Abstract. Piraeus, the third largest city within Greece constitutes one of the most significant ports in the east Mediterranean region. Inhabited since 2,600 B.C. Piraeus evolved to serve as the seaport of Athens that hosted a powerful commercial and military fleet and fortified the city during classical antiquity. Remains of Piraeus past prominence is evident through the numerous archaeological findings found throughout the city. The commercial significance of Piraeus continued in modern history soon after the establishment of the Greek state. Various interventions that included the development of the Athens-Piraeus railway line in 1869, the development of the railway link between Piraeus and the Peloponnese and northern Greece, as well as the development of the Corinth Canal in 1893 contributed in increasing port-traffic and initiating industrial development. The rapid urbanisation and industrialisation process resulted in the city’s environmental degradation. In recent years Piraeus has been subjected to further degradation through de-industrialisation and downsizing of the trade industry. Nature-based solutions (NBS) aim to integrate more nature, natural features and processes within cities, landscapes and seascapes while providing environmental, economic and social benefits and contributing to building resilience. The public authorities together with the stakeholders from the private sector and civil society co- design, create and manage green infrastructure for post-industrial regeneration. The study presented constitutes part of the “proGIreg” project funded by the European Commission programme “Horizon 2020”. A detailed site analysis of the Municipality of Piraeus was undertaken under four thematic headings: Socio-cultural inclusiveness, Human health and wellbeing, Ecological and environmental restoration, Economic and labour market. The main findings of the spatial analysis are presented which lead to the identification of two sites for the use of NBS.

1. Introduction

Piraeus, the third largest populated municipality of Greece, is located along the Saronic coast, 12 km southwest from the capital city Athens and its port constitutes one the most significant in the east Mediterranean region [18]. With a population of 163,688 and surface area of 11.193 km² [14], Piraeus presents a high population density of 14,624 residents per km². Piraeus was inhabited since 2,600 B.C.
[13], and in classical antiquity served as Athens’ fortification and seaport that hosted a powerful commercial and military fleet [3]. Kifissos river, traverses along the east boundary of Piraeus, which formed alluvial soils along its banks, that were fertile and favoured the development of rural settlements [4]. At present Kifissos river is underground and remerges with a highway running over it, just before it reaches the sea. The decline of Piraeus began with the defeat of Athens in the Peloponnesian war (404 B.C.) followed by the attacks of the Romans (85 B.C.), Goths (395), Franes (1205), Ottomans (1456) and Venetians (1687-1688) [3]. During the latter attack the naval commander Morosini bombarded the Parthenon and pillaged the port’s white marble seated lion statue dated since 360 B.C. and that granted during the medieval years Piraeus’ name "Porto Draco" and "Porto Leone" [3]. The lion statue was transferred to Venice and currently constitutes one of the four lions in front of the Arsenal [21]. Soon after the liberation of Piraeus and Athens from the Ottomans in 1828, the founding of the Greek State in 1830, and the relocation of the country’s capital from Nauplio to Athens in 1834, the Municipality of Piraeus in 1833 was established [13][3]. In search for employment and a better life people migrated to Piraeus mainly from the Peloponnesse, Chios and Hydra [3]. In 1834 the architects Kleanthis and Schaubert, developed the first urban plan of Piraeus which was based on the “Hippodamian Plan” by Hippodamus of Miletus, ancient greek architect (498-408 B.C.) and “the father of European urban planning” [16][17][12]. The original plan had undergone many changes due to failures to implement land policy and the unstable economy; these included changes in the lay-out of land uses, the size of building plots and the proportion between building height and street width [16][17]. The economic development of Piraeus and the construction of the Athens-Piraeus railway line in 1869 resulted in a rapid population increase after the mid-1960s. Furthermore the established railway link between Piraeus and the Peloponessse and northern Greece, as well as the development of the Corinth Canal in 1893 increased Piraeus’ port traffic and initiated industrial development [16]. Currently, Piraeus is divided into five city districts. In recent decades even before the beginning of the financial crisis in Greece, Piraeus like many other cities in Europe, has been affected by de-industrialisation and shrinking of the trade activity that has led to the shut-down of many companies and unemployment increase.

Like Piraeus, Europe’s natural capital continues to be degraded, jeopardizing long-term sustainability and undermining resilience to environmental hazards [8]. Expensive built infrastructure also referred to as grey infrastructure has been used extensively to fulfill single functions, whereas nature provides multiple functions that are concomitantly more economic, and environmentally (e.g. conserving biodiversity, adapting to climate change) and socially (e.g. providing green space) sustainable [9]. The European Commission has identified the need to value Europe’s natural capital and invest in green infrastructure [7]. Many EU countries have developed national guidance documents and/or strategies to encourage investments in GI for sustainable spatial planning [10]. Green Infrastructure (GI) is defined as “a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings.” [8].

Overall GI is described as a “tool for providing ecological, economic and social benefits through natural solutions.” [8]. The International Union for Conservation of Nature (IUCN) defines nature-based solutions (NBS) as: “Actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits.” [6]. The IUCN developed eight principles for NBS which state, “NBS: 1. embrace nature conservation norms (and principles); 2. can be implemented alone or in an integrated manner with other solutions to societal challenges (e.g. technological and engineering solutions); 3. are determined by site-specific natural and cultural contexts that include traditional, local and scientific knowledge; 4. produce societal benefits in a fair and equitable way, in a manner that promotes transparency and broad participation; 5. maintain biological and cultural diversity and the ability of ecosystems to evolve over time; 6. are applied at a landscape scale; 7. recognise and address the trade-offs between the production of a few immediate economic benefits for development, and future options
for the production of the full range of ecosystems services; and 8. are an integral part of the overall design of policies, and measures or actions, to address a specific challenge.

In 2016, at an informal meeting held in Amsterdam, the Netherlands, the EU Ministers responsible for Urban Matters established the Urban Agenda for the EU determined in the “Pact of Amsterdam”; herein listed amongst the 12 priorities themes “Sustainable use of land and Nature-Based solutions” with the objective “to ensure that the changes in Urban Areas (growing, shrinking and regeneration) are respectful of the environment, improving quality of life.”. The Action Plan for the “Sustainable use of land and Nature-Based solutions” identified the following NBS actions: 1. Including land take and soil properties in impact assessment procedures, 2. Funding and financing guide for brownfield development, 3. Identifying and managing under-used land, 4. Indicators of land take, 5. Promoting functional urban areas cooperation as a tool to mitigate urban sprawl, 6. Better regulation to boost NBS at European, national and local levels, 7. Better financing on nature-based solutions, 8. Awareness raising in the areas of NBS and sustainable use of land (urban sprawl), 9. Agreeing on common targets and indicators for NBS, urban green infrastructure, biodiversity and ecosystem services in cities. However the Pact of Amsterdam states that the Action Plan is non-binding i.e. not compulsory. Funded by the European Commission programme “Horizon 2020” the project titled “proG1reg” aims to demonstrate the integration of nature-based solutions into business models which are economically self-sustaining and which provide multiple benefits for the economic, ecological and social regeneration of deprived urban areas affected by de-industrialisation. Eight nature-based solutions are considered: 1. renaturing landfill sites for leisure use and energy production, 2. new regenerated soil based on biotic compounds for urban forestry and urban farming, 3. community-based urban farming and gardening on post-industrial sites, 4. aquaponics as soil-less agriculture for polluted sites, 5. capillary green infrastructure on walls and roofs, 6. making post-industrial sites and renatured river corridors accessible for local residents, 7. establishing protocols and procedures for environmental compensation at local level, 8. pollinator biodiversity improvement activities and citizen science project. This study examines the opportunities for NBS in the Municipality of Piraeus based on the results of a detailed spatial analysis under four thematic headings: 1. Socio-cultural inclusiveness, 2. Human health and wellbeing, 3. Ecological and environmental restoration, 4. Economic and labour market.

2. Methodology
Visits were conducted throughout the Municipality of Piraeus to record and map green spaces. Concomitantly different types of data were obtained by the pertinent authorities. These data included: administrative units and land cover obtained by the Municipality of Piraeus; land use obtained by the Government Gazette 79Δ/88 and 663Δ/94; population, employment, education attainment, building construction date, ownership status, obtained by the Hellenic Statistical Authority [14]; cadastral parcels, ownership status, and digital elevation maps (DEM) obtained by the Hellenic Cadastre; and orthoimagery dated in 2010 obtained by the Mapping & Cadastral Organisation of Greece (OKXE). The location of various amenities such as hospitals, schools, nurseries, medical centers, inland revenue, banks, post-offices, libraries, etc. as well as the routes of the various public transport lines were identified by the addresses and maps provided on the websites of the pertinent bodies. The collected information was inserted into ArcGIS, v. 10.5.1 (Esri, Redlands, California, United States) and four thematic maps were developed by Geosystems Hellas S.A. depicting the results of each thematic heading of the spatial analysis. The results and conclusions produced by the spatial analysis is the work of the authors. Specifically, under each thematic heading the following information was depicted [19]:

2.1. Socio-cultural inclusiveness
Population density (m²/person), town hall, municipal theatre, museum, archaeological site, beach, library, university, nursery, school (primary – reception, secondary), church, naval academy, station, beach, highway, avenue, road (primary, secondary), transport line (bus, trolleybus, tram, urban and suburban rail, metro).
2.2. Human health and wellbeing
City blocks with a playground within 250m range, hospital, medical centre, playground, green space, pedestrian zone, archaeological site, beach, cemetery.

2.3. Ecological and environmental restoration
DEM (m), green space, pedestrian zone, archaeological site, beach.

2.4. Economic and labour market
Land use (residential, city centre, commercial local, green space, sports, care, cultural, tourism recreational, particular uses, parking, transit areas, industrial, regeneration Piraeus Avenue, regeneration Ag. Dionisios area), bank, ATM, Inland Revenue, court house, manpower employment organisation, post office.

Following two locations were identified to propose the use of NBS as well as determine the type of NBS for each site.

3. Results and Discussion
Spatial analyses showed that the presence, number and spatial distribution of the elements depicted under each thematic heading differed across the five city districts.

3.1. Socio-cultural inclusiveness
Usual urban development restricts and isolates natural areas [2]. In addition to various amenities, green spaces increase socio-cultural inclusion by providing opportunities for social contact between people of different social groups and participation in open space events [5].

3.1.1. A’ City District. Population density is relatively medium-low; lower population density occurs along the south coastal residential areas that are considered amongst the most affluent within Piraeus whereas higher population density occurs near the local commercial areas which are characterised by buildings containing shops on the groundfloor and offices/flats on the above floors. Along the coast there are, three bays (Palaskas, Aphrodites, Louviari), the Hellenic Naval Academy, Zeas Marine, the cruise terminals of the port, the Hellenic Maritime Museum, the exhibition centre of Piraeus Port Authority S.A. (PPA), as well as archaeological findings that include sections of the city walls dated since 5th century B.C. The bus constitutes the main form of transport and bus lines are distributed throughout the district’s area. The churches, nurseries and schools (primary-reception and secondary) are distributed throughout the district (Figure 1).

3.1.2. B’ City District. Population density is also relatively medium-low; lower population density occurs within the city centre areas containing few residential areas whereas higher population density occurs on the mainland near the local commercial areas and increases with the distance away from the coast. The B’ City District contains important cultural establishments located within the proximity of the city centre such as the Municipal Theatre, Veakio theatre, municipal gallery, Cathedral and the church of the Patron Saint (Agios Spiridonas). The terminals of the passenger port connecting Piraeus with other ports within Greece is located on the west coast in proximity to the urban and suburban rail terminals that connect Piraeus with Athens, the airport, Corinth and indirectly mainland Greece. Ongoing construction is present within the city centre and along the west coast to develop a metro line that would connect to the airport. On the other hand on the south coast there are two marines (Zea and Microlimano). Within the district the bus constitutes the main form of transport. The churches and schools (primary-reception and secondary) are distributed throughout the district whereas the nurseries are mainly concentrated within the city centre area (Figure 1).
3.1.3. C’ City District. Population density is medium and more increased in proximity to the north district boundary. The north district boundary runs along the National Highway connecting Piraeus with Athens while the east district boundary runs along Kifissos river and Kifissos highway supported with pillars above the river. In the south the coast hosts Athina marine and the athletic facilities of the Peace and Friendship Stadium that constitutes a local landmark. The C’ City District also hosts Karaiskaki Stadium; home of Olympiakos football team. The urban rail and bus constitute the main forms of transport. Ongoing construction is present to extend the existing tramline to the passenger port. The churches, nurseries and schools (primary-reception and secondary) are distributed within the residential areas (Figure 1.). However the south west area of the district does not host any nurseries.

3.1.4. D’ City District. The population density is medium-high. The bus and trolleybus constitute the main form of transport which is limited to the main roads. The suburban rail also serves the district through “Lefka” station however the suburban railway track dissects the district in two. The schools (primary-reception and secondary) are distributed throughout the district within the residential areas. However the north area of the district does not host any nurseries, while the central—south area of the district does not host any church (Figure 1).

3.1.5. E’ City District. Within Piraeus the highest population density was present in the E’ City District which is characterised by taller buildings containing more floors (Figure 1). The district is located on
the mainland with only access to the sea through the passenger port. The bus constitutes the main form of transport and bus lines are distributed throughout the district. The churches, nurseries and schools (primary-reception and secondary) are distributed throughout the district.

3.2. Human health and wellbeing
Increased building density have an impact on health. The results of the population density presented above is related to the corresponding building density. Similarly limited in number and size green spaces as well as increased traffic hence air pollution have an impact on health. Generally urban green spaces contribute positively to human thermal comfort, health and well-being [11][1]. Furthermore the promotion of walking and cycling can be considered as a strategy to tackle obesity and chronic disease [15]. Throughout Piraeus cycle routes are not present.

3.2.1. A' City District. Within the district the local commercial areas which also contain residential properties as well as the residential areas located near the east coastline and a small area on the south coastline lack the presence of nearby playgrounds (i.e. located within 250m range). The A’ City District hosts the only two public hospitals of Piraeus (Metaxa Cancer Hospital of Piraeus and Tzaneio Prefecture General Hospital of Piraeus) as well as two private clinics. Furthermore the A’ City District is surrounded mostly by sea and hosts one of the two municipal beaches; Freattydos beach. Relatively small in size green spaces are distributed throughout the district. Due to the absence of metro and urban rail transport, traffic is heavy during rush hours especially along the ports and near the city centre.

3.2.2. B’ City District. The north residential areas of the district lack the presence of nearby playgrounds (i.e. located within 250m range). A relatively large area of the district is surrounded by sea and hosts the municipal beach Votsalakia. Relatively medium-sized green spaces are distributed throughout the district. The absence of a metro and urban rail transport system serving the city centre creates heavy traffic during rush hours.

3.2.3. C’ City District. The residential areas located south of the Poseidonos highway and along Kifissos river lack the presence of nearby playgrounds (i.e. located within 250m range). Only the south area of the district is surrounded by sea, however hosts two important stadiums, one of which is surrounded by green spaces and sports facilities. Relatively small in size green spaces are distributed throughout the district and Kifissos river runs along the east district’s boundary. The district is dissected by Poseidonos highway and Kifissos highway transverses the east district boundary, which are both characterised by constant traffic throughout the day. Considerable traffic is also found on Piraeus avenue located along the north boundary of the district.

3.2.4. D’ City District. The D’ City district is the only district with no access to the sea. The residential areas located south of the suburban railway tracks lack the presence of nearby playgrounds (i.e. located within 250m range). There are few medium sized green spaces within the district. Pireaus Avenue located on the south boundary of the district as well as Thivon Avenue are characterised by traffic. Furthermore the district is dissected by the railway lines of the suburban rail creating problems in accessing green spaces located on either side of the tracks.
3.2.5. E’ City District. The only access to the sea is through the passenger port. The residential areas within the E’ City district are characterised by high building density. The north and west residential areas of the district lack the presence of nearby playgrounds (i.e. located within 250m range). Furthermore there are relatively few medium-large size green spaces located within the district as well as a former railway track. Akti Kondili Road located along the port is characterised by heavy traffic. The cemetery of Piraeus forms part of the district although it is located within the municipality of Drapetsona and is connected to it by a road that also forms part of the district.

3.3. Ecological and environmental restoration
Within the Municipality of Piraeus the total amount of green spaces excluding tree avenues is approximately 134,997 m² that is distributed to approximately 0.83 m²/person. The distribution of green spaces within each district have been mentioned in the previous section. The elevation overall within the Municipality is relatively gentle however rises creating two hills, one in the east and another in the west at an altitude of approximately 96 and 60m above sea level (m.a.s.l.) respectively (Figure 2.).

![Figure 2. Spatial representation of elevation and green spaces within the Municipality of Piraeus (Map Synthesis: Geosystems Hellas S.A.).](image)

3.3.1. A’ City District. The elevation rises gradually towards the centre of the district reaching approximately 50 m.a.s.l.

3.3.2. B’ City District. To the east of the district the elevation rises gradually to approximately 14 m.a.s.l whereas to the west the elevation rises gradually reaching the highest altitude within the Municipality, at Profitis Ilias hill with an elevation of approximately 96 m.a.s.l.
3.3.3. **C’ City District.** The terrain within the district is relatively gentle reaching approximately 10 m.a.s.l.

3.3.4. **D’ City District.** The terrain within the district is relatively gentle reaching approximately 10 m.a.s.l.

3.3.5. **E’ City District.** Most of the district’s elevation ranges between 20-30 m.a.s.l. and gradually rises to the north reaching approximately 60 m.a.s.l. The E’ City District possesses the only cemetery of Piraeus which is located within the boundaries of the Municipality of Drapetsona.

### 3.4. Economic and labour market

The economic and labour market of the Municipality is mainly located within the B’ City District and secondary to the north area of the A’ City district. Both the C’ City District and E’ City District are characterised by a limited economic and labour market. The introduction of GI can provide quantitative benefits, in the form of financial returns [20].

3.4.1. **A’ City District.** The A’ City District (area 2,358,748 m²) is surrounded mainly by sea. Part of the city centre is located in the north while the remaining area is characterised by residential and local commercial use.

3.4.2. **B’ City District.** The B’ City District (2,058,999 m²) hosts Piraeus’ city centre and high street and contains important legislative establishments. The city centre occupies approximately half of the district’s area while the remaining half is characterised by residential and local commercial use. A small area along the north boundary is industrial but characterised as not particularly obtrusive.

3.4.3. **C’ City District.** The C’ City District (1,770,164 m²) is the smallest in size district area of the Municipality of Piraeus. It is characterised mainly by residential and local commercial use. The area along the north boundary where several industries are located such as Xropei (paint), Elais (olive oil), and Ion (chocolate) is scheduled for regeneration. Industries characterised “not particularly obtrusive” are located along Mikras Asias highway on the west boundary of the district. The economic and labour market is concentrated mainly near the Peace and Friendship Stadium and Karaiskaki Stadium.

3.4.4. **D’ City District.** The D’ City District (2,211,691 m²) does not possess access to sea and is characterised mainly by residential and local commercial use. Industries characterised “not particularly obtrusive” are located along the south boundary of the district.

3.4.5. **E’ City District.** The district is mainly characterised by residential and local commercial use. The area containing the facilities of the former Papastratos industry is scheduled for regeneration. The economic and labour market is concentrated mainly in the marine near the passenger port.

Considering the above, Kifissos river located within the C’ City district and the former railway track located within the E’ City district (with the highest building density) present opportunities for providing the residential areas with both new green spaces and green corridors connecting to the sea.

### 4. Conclusion

The study shows that the Municipality of Piraeus presents opportunities for urban regeneration through NBS. The main strengths identified include the sea location, two raised locations offering panoramic views, many archaeological sites, churches and former industrial sites with significant local as well as national historical and cultural value. On the other hand the main identified weaknesses include the private ownership of former industrial sites, high building density and limited green network and increased traffic hence pollution along main roads and the port. Opportunities exist to “recycle” abandoned industrial buildings for new use and regenerate industrial open spaces, develop a green
network to connect green spaces and a cycle route. Private ownership and potential pollution of former industrial sites that might require clean-up constitute potential threats for the regeneration of the derelict areas. Two linear sites are proposed for developing NBS. One site located within the C’ City District runs along Kifissos river and the other site located within the E’ City District runs along a former railway track (forming a Y). Considering the restricted availability of green spaces and the high building density presented above as well as the potential economic returns through the introduction of GI [20], among the various types of NBS it is proposed to use capillary GI on walls and roofs. The other NBS considered is to renature and make accessible to local residents the river corridor Kifissos as well as to connect the high building density mainland to the sea.

Based on the study’s finding further detailed work is necessary to develop a masterplan. The aim would be to enhance the local history linking the past with the future, revive the memories of the older in age people and former industry workers and regenerate the neighbourhoods surrounding the industrial areas even if within the industrial site boundaries development is unfeasible due to private ownership. NBS can provide the means of achieving the above-mentioned aim.

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