A GIS Referenced Methodological Approach for the Brownfield Redevelopment

Alfonso Ippolito[1], Yasmine Selim[2], Francesco Tajani[3](✉), Rossana Ranieri[3], and Pierluigi Morano[4]

[1] Department of History, Design and Restoration of Architecture, Sapienza University of Rome, 00186 Rome, Italy
[2] Department of Architecture, Faculty of Engineering, Ain Shams University, 11566 Cairo, Egypt
[3] Department of Architecture and Design, Sapienza University of Rome, 00196 Rome, Italy
francesco.tajani@uniroma1.it
[4] Department of Civil, Environmental, Land, Building Engineering and Chemistry(DICATECh), Polytechnic University of Bari, 70126 Bari, Italy

Abstract. In the perspective of a sustainable development of the urban territory, the aim of this research is to define a methodology for the characterization of a brownfield inventory, accessible by the government and the private investors to facilitate decision making, by reaching the needed information upon land capability, development incentives, public goals, interests and preferences, environmental concerns. This issue is very current, taking into account the numerous researches on the urban development of the cities and how the urban sprawl caused the industrial areas that initially existed on the city outskirts to become a part of the city center. This rapid growth motivates the governments and private investors to look at these abandoned industrial buildings as important assets. The research discusses a decision support framework and the benefits of access to geospatial databases in the decision-making process.

Keywords: Brownfield · GIS · Decision support systems · urban redevelopment

1 Introduction

Brownfields are properties that have been contaminated by hazardous substances and are often derelict or underused. These properties pose potential health and environmental risks, and their redevelopment can be costly and complex [1]. Industrial heritage, on the other hand, refers to the historical legacy of industrial activities and the built environment that results from them. Industrial heritage sites may include old factories, warehouses, and other industrial structures, and they may be considered for preservation for their cultural and historical value [2]. While both brownfields and industrial heritage sites may be found in urban areas, they are distinct concepts and are managed differently. The International Council on Monuments and Sites (ICOMOS), and the International Committee for the Conservation of the Industrial Heritage (TICCIH), acknowledge the

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particular nature of industrial heritage and the issues and threats around it, stating that "industrial heritage is highly vulnerable and often at risk, often lost for lack of awareness, documentation, recognition or protection but also because of the changing economic trends, negative perceptions, environmental issues or its sheer size and complexity." [2]. At the same time, physical revitalization and functional restructuring, adaptation of industrial heritage to the needs and requirements of post-industrial society, as well as the aspect of economic revitalization through new ways to utilize an industrial building stock is a matter that is repeatedly talked about regarding industrial heritage. In view of that, the importance of the sustainable conservation of industrial heritage is also recognized. "By extending the life cycle of existing structures and their embodied energy, conservation of the built industrial heritage can contribute to achieving the goals of sustainable development at the local, national, and international levels. It touches the social as well as physical and environmental aspects of development and should be acknowledged as such" [2].

In Central and Eastern Europe, but also elsewhere, de-industrialisation has produced veritable "black holes" in the *Forma Urbis*: in Great Britain it is estimated that there are 128.000 hectares of abandoned land, in France 20,000, in the Netherlands 10,000, in Italy 9,000 and in Switzerland 1,700. Those lands are frequently areas without purpose, filled with rubbish and industrial waste, which have lost their "*raison d'être*" and are awaiting some form of regeneration. [3]. Unused and underused buildings and spaces represent enormous potential for cities; they often exist in desirable waterfront lands, city centers and old industrial zones. Alteration of values generated by functional restructuring, is a subject which is often left behind the general discussion about sustainable conservation and adaptive reuse of industrial heritage. This is because the focus is often on the physical preservation and conservation of industrial heritage sites, rather than on the changes in the values associated with these sites.

The post-industrial society is a term coined by the sociologist Daniel Bell [4] to describe the current state of society in developed countries, in which the service sector has come to dominate the economy and manufacturing has become less important. This shift is often accompanied by changes in social and cultural norms, as well as in the political and economic systems. Some of the key theories of the post-industrial society include: the information society theory, which suggests that the rise of information and communication technologies has led to the growth of the service sector and the decline of manufacturing; the knowledge economy theory, which posits that the value of knowledge and expertise has become more important than physical labor in driving economic growth; the flexible specialization theory, which argues that the post-industrial economy is characterized by the rise of small, specialized firms that are able to quickly adapt to changing market conditions; the cultural capitalism theory, which suggests that the post-industrial society is driven by the production and consumption of cultural goods, such as music, art, and fashion. Overall, the theories of post-industrial society highlight the ways in which the economy and society are changing in response to technological, social, and cultural shifts.

Considering the aesthetic of brownfield and the shift of the modern society needs, there is a demand for spaces that are flexible and different. Industrial heritage fits this scheme, establishing itself in the landscape of contemporary art and culture. Old factories

can be transformed into cultural spaces in a variety of ways: repurposing the factory as a museum or exhibit space, it could involve showcasing the history of the factory and its role in the local community, or it could involve hosting temporary or permanent exhibits on a variety of topics. A great example of this reuse is *Centrale Montemartini* in Rome (Fig. 1). An old factory can also be transformed into a venue for concerts, theatre performances, or other live events, *Rawabet* Theatre in Downtown Cairo (Fig. 2) is a successful example of this transformation from an old car warehouse to a theatre hosting cultural events. Another reuse example is *SpazioMen*sa (Fig. 3), located inside the former paper mill in Rome divided into smaller spaces that are used as artist studios or galleries, allowing local artists to work and exhibit their work in a shared space. Also, the *Mattatoio* that was inaugurated in 1890, decommissioned in 1975 and remained an empty shell for many years. Most of the old pavilions still stand empty and are closed to the public. However, others are now to a contemporary art space and architecture school (Fig. 4).

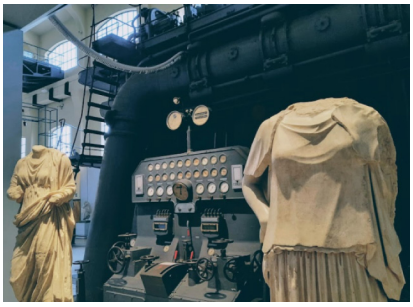


Fig. 1. Cent. Montemartini, Rome



Fig. 2. Rawabet Theatre, Cairo



Fig. 3. SpazioMensa, Rome



Fig. 4. Mattatoio, Rome

The Industrial Revolution left substantial marks on the appearance of cities, certain stereotypes and a negative image of industrial urban landscape emerged, which was reinforced by many depictions of the rough aesthetic of the heavy industrial architecture in cities and of the pollution that came with it. De-industrialization crisis and the profound structural change enriched the negative image by leaving numerous disused industrial spaces, run-down factories, and industrial complexes behind. Being aware of the socio-cultural formation of post-industrial Western societies, their tendencies, and dynamics, is crucial to understand the evolution of the post-industrial urban landscape

and the transformation of its single elements, e.g., post industrial production spaces and the current strategies of their management. Nonetheless, it is important to consider the alteration of values generated by functional restructuring when planning for the sustainable conservation and adaptive reuse of industrial heritage. This is because changes in values can have a significant impact on the long-term sustainability of these sites. For example, if the values associated with an industrial heritage site are altered in a way that makes it less appealing to visitors or less valuable to the local community, it may become difficult to generate the resources needed to preserve and maintain the site over time. This can involve engaging with local stakeholders and communities to understand their priorities and concerns, as well as conducting research to identify the potential consequences of functional restructuring. By taking these factors into account, it is possible to develop conservation and adaptive reuse strategies that both preserve the physical heritage of industrial sites and support the long-term sustainability of these sites.

The work is organized in the following Sections. In Sect. 2, an analysis of the current literature on brownfields and the methods/technique to assess them is reported. In Sect. 3, the methodological approach and its main phases are illustrated. In Sect. 4, the conclusions and possible further insights are drawn.

2 Literature Review

Urbanized spaces are undergoing major changes due to the higher number of people moving to the city. In particular, urban transformation and deindustrialization in advanced economies have left numerous vacant and abandoned lands that can become an opportunity for positive city improvement [5–7]. With the aim to reduce land consumption, Public Administrations have begun to pay more attention to the issue of brownfields redevelopment. There are numerous contributions in current literature that propose tools and methodological approaches for the analysis of brownfield and related transformation projects [8–11]. According to these studies, the assessments of brownfield programs could be complex, especially because there are no available databases for tracing ample information on policy activity. In this sense, Bacot and O'Dell [12] have tried to identify proper environmental criteria for analyzing local government brownfield programs; Hartmann et al. [13] have proposed a multi-objective examination and evaluation method for extensive analysis of the conditions of the brownfields, in order to support investor that aims to utilize the property for energy generation purposes. The energy purpose redevelopment of brownfield sites is frequent: there are in fact many studies related on wind and solar power, biopower, waste, and mixed uses [14–18]. Those studies highlight that is important to take the social aspects into consideration, by revitalizing urban areas and involving local governance and communities in the projects. In particular, Wang et al. [19] have proposed a quantitative methodology to support negotiations on the allocation of costs and benefits in brownfield redevelopment projects applying cooperative game theory.

Another key aspect of brownfield management is related to the ability for city planners to have access to georeferenced quantitative information. In this regard, Geographic Information System (GIS) tools have been very effective in managing urban planning and real estate developments, with particular reference to brownfields [20–22]. Ahamad

et al. [23] have developed a consensus-based brownfield definition and an evaluation index system to evaluate brownfield redevelopment in Pakistan using a methodology combining Triangular Fuzzy Numbers and Grey Relational Analysis. Aktas et al. [24] have proposed a method to screen numerous brownfields over large geographic areas by using GIS and to assess and prioritize such sites for green building suitability based on leadership in energy and environmental design criteria. Thomas et al. [25], in order to evaluate land use options with respect to brownfields inventory, characterization, and potential for redevelopment, have defined a GIS based land use modeling application to support decision system that provides access to state, regional, and local geospatial databases, several informational and visualization tools, and assumptions useful in providing a better understanding of issues, options, and alternatives in redeveloping brownfields. Furthermore, Li et al. [26] have integrated the Data Envelopment Analysis method with a GIS based site selection systems that can determine the most suitable site objectively and visually. Zeng et al. [27] have developed a prototype real estate GIS by integrating fuzzy set theory, a rule-based system and GIS.

3 Methodological Approach

Referring to Anne Lacatan's approach "Never demolish. Never subtract, remove, or replace. Always add, transform, and utilize, with and for the inhabitants" [28]. Adaptive reuse refers to the process of repurposing or converting an industrial building for a new use, rather than demolishing it and starting from scratch. This approach can be a sustainable and cost-effective way to reuse existing buildings and infrastructure, and it can also help to preserve the character and history of a place.

The main objective of adaptive reuse is to give new life to existing buildings or sites that are no longer being used for their original purpose. Raising the awareness and appreciation of industrial heritage is another objective of adaptive reuse, preserving historical or cultural landmarks can support to protect important buildings, structures, and sites that may have architectural, historical, or cultural significance. This can maintain the character and sense of place of a community and can also support local tourism and economic development. Heritage recycling has a great impact on environment preservation, reducing waste and thus allowing for the reincorporation of old materials, to reduce the amount of waste generated by demolishing old buildings and constructing new ones. It can also minimize the environmental impact of development by reducing the amount of energy, water, and other resources required to build new structures. This leads to the economic benefits of the brownfields redevelopment creating commercially viable assets for owners and users: adding to the economic and environmental benefits the social well-being by the adaptation of spaces according to the community and stakeholders needs; designing accessible, usable public places can support sustainability and resilience by promoting the use of existing infrastructure and resources, and by helping to create compact, mixed-use developments that can support diverse and vibrant communities; providing opportunities for designers and developers to think outside the box and to come up with creative solutions for repurposing old buildings and sites, to foster a sense of ingenuity and entrepreneurship within a community [29].

Noting that the benefits provided by a framework for brownfields redevelopment are aligning with the adaptive reuse goals and benefits, it leads to following a similar strategy approaching the brownfields redevelopment planning.

The phases of adaptive re-use of brownfields can be divided into the following steps:

i. Mapping. This involves creating an inventory of brownfields in the area, including information about ownership, environmental conditions, and potential uses. This step helps to identify the properties that are suitable for redevelopment.
ii. Visualising. This phase involves collecting ideas and proposals from the community and stakeholders for the re-use of the vacant properties. This can include public input sessions, design competitions, and other methods of engaging the community in the planning process.
iii. Decision making and financing. This phase involves evaluating the economic and social impact of different alternatives for the use of the brownfields. This may include analysing the feasibility of different development proposals, considering the costs and benefits of each option, and identifying potential sources of funding.
iv. Evaluating. This final phase involves creating a mechanism for collecting feedback and modifying the strategy as needed. This may involve ongoing monitoring of the redevelopment process, soliciting feedback from the community, and adjusting the plan as needed to ensure that the redevelopment meets the needs and goals of the community.

3.1 Road Map

Reusing brownfields can be a challenging process due to several barriers, including environmental contamination, as many brownfields are contaminated with hazardous substances, which can be expensive and time-consuming to clean up; liability concerns, as property owners may be liable for any environmental contamination that occurs on their property, which can be a deterrent to reuse. The unknown remediation costs associated with brownfield clean up and redevelopment can make it difficult for developers to secure financing for these projects; complex regulatory environment, as brownfields are often subject to a variety of state regulations, which can be complex and time-consuming to navigate; community opposition, as local communities may resist the reuse of brownfields due to concerns about environmental impacts or other issues; limited availability of technical assistance, as developers may lack the technical expertise or resources needed to navigate the complex process of brownfield reuse.

In order to overcome these barriers, both the government and the private investors need an easily accessible database to assess the criteria of redevelopment and facilitate the brownfields redevelopment not only on the public municipal level, nor on the financial revenue to private entities, but also on the public-private partnership approaches [30]. Public-private partnerships can be a useful tool for brownfields development that can support the challenges associated with brownfields development by bringing together the resources and expertise of both the public and private sectors. One key benefit is that the financial burden and risk associated with cleaning up and developing contaminated properties are spread over both parties. The public sector can finance, regulatory support, and other resources, while the private sector can bring expertise, innovation, and financial resources to the table. Assessing the reduction of i) the cost of brownfields development

and making it more feasible for both the public and private sectors, ii) the amount of time and effort required to clean up and regenerate contaminated properties, which in turn stimulate economic growth and revitalize communities [31].

The use of decision support systems in the business world is well established. According to Sauter [32], decision support systems, by definition, should aid in and strengthen the process of choice. The goal of a Decision Support System (DSS) is to provide users with the information and tools they need to make informed decisions. This includes understanding the needs and abilities of the user, as well as the context in which the information will be used. To be effective, a land use decision support system must ensure access to data, the tools or mechanisms to transform data into useful information, and the context from which understanding is derived. With the addition of GIS-based models and other analytical tools, decision-makers can begin to manipulate data in a true planning environment [25].

A decision-support framework for brownfields development can be a useful tool to help alter the narrative of brownfields and make them more competitive with Greenfields. There are several benefits to having such a framework in place. A decision-support framework can guarantee a structured approach for evaluating the potential of a brownfield site, including its environmental, economic, and social impacts. Decision-makers can use this to swiftly find the most promising sites and forward development plans and can also demonstrate the viability of a brownfields development project, making it more attractive to potential funding sources.

Based on the project marketability it will attract different approaches of funding, as generally more marketable brownfield development projects are more likely to attract private funding, while less marketable projects may be more reliant on funding from government sources and medium marketable sites depend more on public-private partnerships. Factors that may influence the marketability of a brownfield development project include the location of the site, the potential for economic development, and the environmental risks and liabilities associated with the site. Projects that are located in high-demand areas, have a clear economic benefit, and pose minimal environmental risks are likely to be more marketable and therefore more attractive to private investors. On the other hand, projects that are located in less desirable areas, have uncertain economic prospects, or pose significant environmental risks may be less marketable and may need to rely on government funding sources.

When creating a decision-support framework, it is crucial to take the marketability of a brownfield development project into account as it can assist identify the most suitable funding sources and guarantee that the project has the resources it needs to be successful.

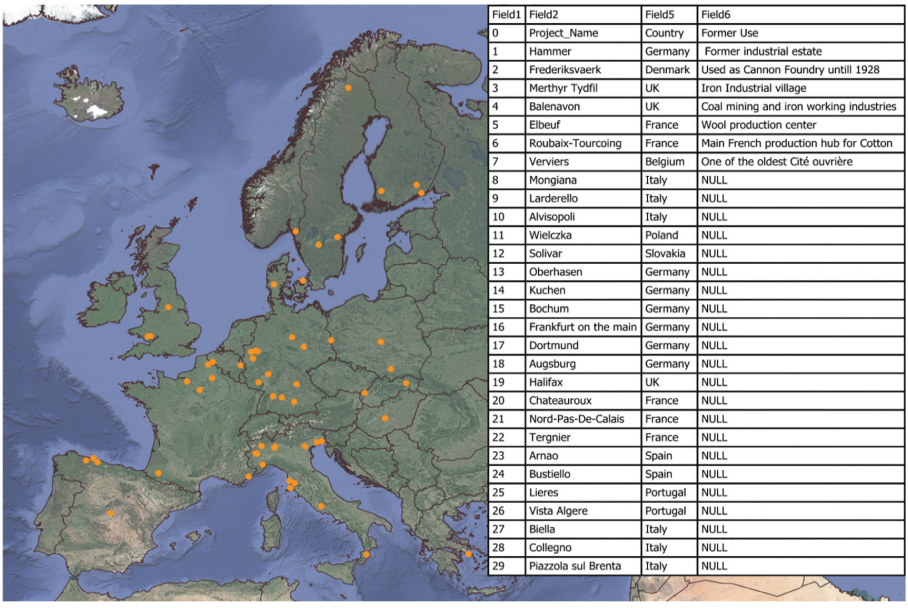
There are several benefits to using a framework for the stakeholders. Investors, by analyzing data and alternative uses, can make informed decisions about which projects to invest in and can potentially reduce financial risk. The framework assesses the government to easily track and manage brownfield sites, which can be incorporated into city planning and development decisions. From a community perspective, the framework ensures that development projects align with the needs and priorities of the community as identified through surveys and other forms of public input. Non-governmental organizations (NGOs) can use a framework to focus on both community needs and environmental issues, helping to ensure that development projects have a positive impact on

both people and the environment. Providing urban planners with access to data and surveys that can support them prioritize development projects and make informed decisions about how to use land and resources in the most effective and efficient way.

The main goal of this project is to develop a *vademecum* that could help local governments and developers make informed decisions about the development of brownfield sites. It would use GIS-based visualization models and decision criteria, as well as access to various geospatial databases and web-based tools that inventory brownfield sites, to help users assess the feasibility of different development options. The system has been designed to be accessible and affordable for local governments and developers, and to involve extensive public input and engagement.

3.2 Description of GIS Approach

To create the inventory of brownfields, the first step is identifying the potential sites in the targeted geographical area. The study was done using QGIS, an open-source geographic information system, also using data from online public sources e.g., Rome Transportation map, *Geoportale cartografico* [33]. Figure 5 shows some of the industrial sites in Europe collected during this study, located with coordinates on QGIS and using the software in registering related data to the site, e.g. current and previous ownership, previous use, current use, structure condition, all collected in one database to show the efficiency of the system in data accessibility and analysis [34, 35].



Field1	Field2	Field5	Field6
0	Project_Name	Country	Former Use
1	Hammer	Germany	Former industrial estate
2	Frederiksvaerk	Denmark	Used as Cannon Foundry untill 1928
3	Merthyr Tydfil	UK	Iron Industrial village
4	Balenavon	UK	Coal mining and iron working industries
5	Elbeuf	France	Wool production center
6	Roubaix-Tourcoing	France	Main French production hub for Cotton
7	Verviers	Belgium	One of the oldest Cité ouvrière
8	Mongiana	Italy	NULL
9	Larderello	Italy	NULL
10	Alvisopoli	Italy	NULL
11	Wielczka	Poland	NULL
12	Solivar	Slovakia	NULL
13	Oberhasen	Germany	NULL
14	Kuchen	Germany	NULL
15	Bochum	Germany	NULL
16	Frankfurt on the main	Germany	NULL
17	Dortmund	Germany	NULL
18	Augsburg	Germany	NULL
19	Halifax	UK	NULL
20	Chateauroux	France	NULL
21	Nord-Pas-De-Calais	France	NULL
22	Tergnier	France	NULL
23	Arnao	Spain	NULL
24	Bustiello	Spain	NULL
25	Lieres	Portugal	NULL
26	Vista Algere	Portugal	NULL
27	Biella	Italy	NULL
28	Collegno	Italy	NULL
29	Piazzola sul Brenta	Italy	NULL

Fig. 5. Demo of mapping industrial heritage sites in Europe and registering variable data on QGIS

Using open-source GIS software (QGIS) to find the data related to the targeted geographic area, not only analyzing the data available from the local government but

also collecting data from the urban planners' surveys and benefiting from the modern technology having public community surveys about the brownfield area. Data including the location and characteristics of brownfields in the area can be used and analyzed on the QGIS, as well as data on the surrounding community, such as population demographics, land use, and infrastructure. Collecting and analyzing data is just one step in the process of considering brownfield redevelopment. It is also important to engage with the community and other stakeholders to ensure that any redevelopment plans take into account the needs and concerns of the community.

Open data GIS can be used by community stakeholders and decision makers to help them consider the reuse of brownfields in their community. This could include data and analysis at the neighborhood level, and help stakeholders track brownfields and consider the potential benefits and impacts of different redevelopment options for existing residents. Using GIS technology could help decision makers make informed decisions about brownfields redevelopment, which can have a significant impact on the community. Redevelopment of brownfields can promote economic and social benefits, such as creating jobs, revitalizing the local economy, and improving the overall quality of life in the community. However, it is important to carefully consider the potential impacts on existing residents, including any potential negative effects on the environment or public health. It is important to involve the community in the decision-making process and to ensure that any redevelopment plans take into account the needs and concerns of the community. This can be done through community engagement efforts, such as holding public meetings, using geotagged surveys, seeking input from local organizations, and working with community leaders.

The relevant level of resolution will depend on the specific decision-making context. There are many different types of data that can be useful to consider when making decisions about brownfields redevelopment using a GIS system. Some of the key data include: location and characteristics of brownfields (e.g. location, size, condition of brownfields in the area, as well as information about any contamination or other environmental issues that may need to be addressed); community data including population demographics, land use, and infrastructure. This can help decision makers understand the potential impacts of brownfields redevelopment on the community and ensure that any plans take into account the needs and concerns of the community; economic data on employment, income, and other economic indicators, as well as data on the potential economic benefits of different brownfields redevelopment options; environmental data on air quality, water quality, and other environmental factors that could be impacted by brownfields redevelopment; social data indicators, such as housing, education, and public health, as well as data on the potential social impacts of different brownfields redevelopment options. Table 1 shows some of these criteria and the possible data sources.

By collecting and analyzing this data using a GIS system, decision makers can get a more complete picture of the potential benefits and impacts of different brownfields redevelopment options and make informed decisions about the reuse of these sites.

Table 1. Synoptic framework of the criteria to be considered for an effective brownfield redevelopment

Site Criteria	Stakeholder questions	Possible answers
Land area	Is the site large enough?	Area (sqm)
Existing contamination	Is the site ready for development? Are there remediation costs before development?	Cost (Euros)
Land Use and land cover	Is the site vacant? What is the existing land use?	Location Survey
Land Value	What is the land purchase cost?	Valuation (euro/sqm)
Incentives	How will the site attract development?	Survey for local financial incentives
Targeted users	Will the proposed use be attractive for users?	Demographic and economic data of the area
Appropriate Zoning	Is the proposed development suitable with the city planning?	Municipality planning
Population demographics	Does development provide a variety of social and economic opportunities?	Demographic and economic data of the area
Community Involvement	Development impact on community improvement, safety, and benefits?	Surveys
Proximity to transportation	How well is the site connected to the city?	Physical survey for transportation accessibility
Existing infrastructure condition	Does water, telephone and different services need upgrade?	Municipal sources and Area surveying

3.3 Framework for Brownfield Redevelopment

The framework for brownfield redevelopment involves the following steps.

1. *Target geographic areas*. To import data from land surveys and local information sources for a specific geographic area, identifying the sources of data that are relevant to your research or project. These may include land surveys, municipal urban planning documents, local government websites.
2. *Identify brownfield sites*. Identifying brownfields on the maps, benefiting from the GIS systems for mapping to visualize and analyze the brownfield sites identified. Overlaying additional data, such as environmental data or demographic information, to understand the potential impact of the sites on the surrounding community. Analyzing the potential risks and challenges associated with each site, such as the extent and type of contamination, the feasibility of clean-up and redevelopment, and any

legal or regulatory barriers that may be in place, to prioritize which sites to focus on first and develop strategies for addressing the challenges they pose.

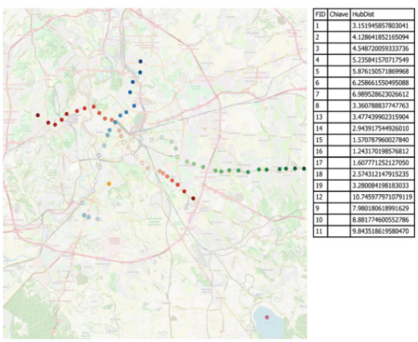
3. *Traditional Source of Funding based on marketability*. It is important to note the marketability of the project, as a factor that can influence the availability and terms of funding from these sources. Funding sources for redevelopment vary based on the site's intended use.
4. *Screen potential community benefits*. Evaluating the potential impacts of the project on the local community and identifying opportunities for the project to provide benefits that go beyond the financial returns to the developer or investors. Some Important points for community development are job creation, community amenities, economic development by attracting new businesses, increasing property values, or generating tax revenues for the community, and environmental benefits by incorporating sustainable design elements and the rehabilitating of the existing property.
5. *Evaluate impacts of cultural redevelopment*. Since contaminated fields cannot be used as residential for health and hazards risks, most municipalities intend them for cultural and commercial uses. Which may involve the development of parks, museums, or other cultural amenities, or the construction of commercial or industrial buildings. These types of uses may be considered less risky from a public health perspective because they typically do not involve long-term exposure to the site by residents. Cultural redevelopment projects can also impact the cultural heritage and identity of the local community. These impacts may be positive, if the project helps to preserve or celebrate the cultural heritage of the area, or negative, if the project involves the demolition or alteration of significant cultural landmarks or ignores the cultural values and traditions of the community.
6. *Develop strategy for redevelopment activities*. Brownfield sites can also pose challenges for cultural and commercial development. These sites may require significant clean-up and remediation efforts to address the contamination, which can be costly and time-consuming. In addition, there may be legal or regulatory barriers to development on brownfield sites, such as liability concerns or restrictions on land use. As a result, it can be important for municipalities to carefully evaluate the feasibility and risks of cultural and commercial development on brownfield sites.

One of the city's most notable abandoned sites is the former "Fiera di Roma", which is located in the VIII Municipality. With resolution no. 66 of July 3, 2014, the Capitoline Council began the process of developing an urban variation, confirming the interest in its redevelopment and upgrading. The Municipal Administration of Rome has in fact decided to involve citizens in selecting which interventions and works they want to see carried out in the area of the Municipio, using the economic resources allocated by private operators within the convention [36].

The Municipal Administration of Rome has a dual purpose in executing this project: on one hand, starting a regeneration process to reshape the area, possibly impacting the entire neighborhood, and, on the other hand, creating a building that is both multifunctional and innovative, able to combine the hopes and needs of a community with the demands and the potential of the institutional partner involved [37].

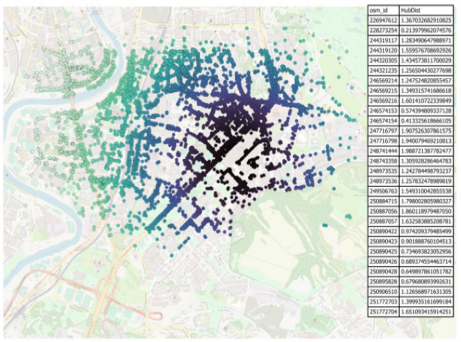
The former "Fiera di Roma" is an excellent illustration of the advantages of data visualization using QGIS, using the accessible GIS data and with the potential for public

surveys with the locals, demonstrating the potential of available data and how it may assist in the creation process and final decision-making. By means of the available online data, an accurate analysis of distances of the neighboring services can be carried out. Figures 6 and 7 respectively describe the distances of several metro lines and the density of bus stops in relation to the site of the former "Fiera di Roma", highlighting the importance of service availability.



FID	Chiave	HubDist
1		3.151945857803041
2		4.128641852165094
3		4.548720059333736
4		5.235841570717549
5		5.876150571869968
6		6.258661550495088
7		6.989528623026612
8		3.360788837747763
13		3.477439902315904
14		2.943917544926010
15		1.570787960027840
16		1.243170198576812
17		1.607771252127050
18		2.574312147915235
19		3.280084198183033
12		10.74597797107919
9		7.980180618991629
10		8.881774600552786
11		9.843518619580470

Fig. 6. Metro lines around the former "Fiera di Roma, colour coded according to distances.



osm_id	HubDist
226947612	1.367032682910825
228273254	0.213979962074576
244319117	1.283490647988971
244319120	1.559576708692926
244320305	1.434573811700029
244321235	1.256504430277698
246569214	1.247524820855457
246569215	1.349315741686618
246569216	1.601410722339849
246574153	0.574394809337128
246574154	0.413325618666105
247716797	1.907526307861575
247716798	1.940079469210813
248741444	1.988721387782477
248743358	1.305928286464783
248973535	1.242784498793237
248973536	1.257832478989819
249506763	1.549310042855538
250884715	1.798002805980327
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250887057	1.632583885208781
250890422	0.974209379485499
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250890426	0.689374554463714
250890428	0.649897861051782
250895828	0.679680893992631
250906510	1.126568971631305
251772703	1.399935161699184
251772704	1.651093419914251

Fig. 7. Density of bus stops around the former "Fiera di Roma", colour coded according to distances.

4 Conclusions

One of the main objectives for using GIS analysis is related to the redevelopment project prioritization. The GIS maps the location and extent of contaminated sites, and allows to identify potential risks and impacts on human health and the environmental context. These information data can be used to prioritize brownfield sites for clean-up and redevelopment, and to elaborate strategies for mitigating any potential risks. Secondly, the GIS analysis gives an integrated tool that includes not only data from municipal sources, but also from community surveys; furthermore, all the geospatial data available are also taken into account, such as demographic, land use, environment and transportation. This allows decision-makers to get a more complete picture of the social, economic, and environmental factors that may impact brownfield regeneration efforts [38–42]. Lastly, it allows to create interactive maps and other visualizations that can be easily shared with stakeholders and the public entities. This can effectively support the brownfield regeneration projects and let the communities know about the potential benefits and impacts of these projects.

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