European Transport \ Trasporti Europei (2023) Issue 93, Paper n° 11, ISSN 1825-3997

https://doi.org/10.48295/ET.2023.93.4

Mobility and land-use system in the sport mega-events. The case of the Cagliari stadium (Sardinia, Italy)

Ginevra Balletto [1], Francesco Sechi [2], Giuseppe Borruso [3*], Martina Sinatra[4], Italo Meloni[5], Gianfranco Fancello[6]

[1] *Associate Professor, Department of Civil, Environmental Engineering and Architecture, Cagliari, Italy - balletto@unica.it*
[2] *Administrator of the MLab srl - https://mlab-srl.com/*
[3] *Associate Professor Department of Economics, Business, Mathematics and Statistics, Trieste, Italy - giuseppe.borruso@deams.units.it*
[4] *PhD Student of Cycle XXXVIII - NRRP scholarship, DD.MM. 352/2022, Department of Civil, Environmental Engineering and Architecture, Cagliari, Italy - m.sinatra@studenti.unica.it*
[5] *Full Professor, Department of Civil, Environmental Engineering and Architecture, Cagliari, Italy - imeloni@unica.it*
[6] *Associate Professor, Department of Civil, Environmental Engineering and Architecture, Cagliari, Italy - fancello@unica.it*

Abstract

The evaluation of the mobility of the Sport infrastructures associated with Mega Events (SMEs), as football stadiums, and, in particular, the modal choices adopted by participants, are the focus of this study. Mobility, geographical aspects and urban planning that characterize a city hosting the SME are the main fields of investigation. In particular, in Italy there is a limited collaborative convergence among technical and scientific principles and the rules expressed by the Italian National Olympic Committee (CONI), to which an obsolete regulation for the accessibility of sports facilities refers. The progressive awareness of the communities on the fundamental role of sustainable mobility, energy efficiency, reduction of air pollution, also deriving from the impulse of the 2030 objectives, highlights how it is illusory to think of reaching them without gradual changes in the lifestyle of the communities themselves through political rules of urban development. Furthermore, the pandemic and the recent energy crisis highlighted the need to develop integrated systems - considering geographical, urban and regional planning, transport and mobility issues capable of innovating to improve planning activities and the quality of urban life.

Keywords: Sport City; Mega Events planning; SDGs; Spatial Proximity; 15-minute City.

1. Sport activities, industry and mega events

The complex urbanization process had consequences on the entire life of communities and, at the same time, represented a break with previous centuries. Although for over 50 years the theoretical assumption was based on the similarity between cities and ecosystems, it is now clear that cities consume and degrade the natural capital at a higher rate than it is able to generate. These are growing dissipative ecosystems, as demonstrated by the overshoot day trend (Earth Overshoot Day website). Furthermore, after a long historical phase of demographic and urban growth - today especially in Europe and in Italy in particular - the population is almost stable, whereas cities continue to grow (Barbosa et al., 2017; Romano et al., 2017). In Italy, urban growth and sprawl are also amplified by individual vehicular mobility, which has driven the spatial diffusion of cities into a vicious circle over the years.

With the pandemic, the model of urban proximity and/or 15-minute city has been introduced and boosted, with sustainable forms of mobility i.e. an integrated, multi-connected and efficient mobility system joining collective and individual transport - Public-Private - in sharing - aimed at achieving the European goal of climate neutrality with zero emissions by 2050 (Russo, 2022). In this sense, the experience of the pandemic and the transitions in progress offer the possibility of rethinking a model of sustainable mobility also for SMEs.

1.1 The controversial Sport Mega - Events (SMEs).

SMEs require increasingly multi - and transdisciplinary approaches, precisely because of the growing urban-territorial complexity (Balletto et al., 2022).

The prevalence of SMEs, in fact, takes place in urban contexts, with consequent externalities - positive and negative - for the local community. There are many issues to be addressed, including governance, infrastructure planning and related environmental impacts, as well as the complex resistance to welcoming SMEs. Furthermore, SMEs are also criticized, because they are often not compatible with the sustainability principles (SDGs) (Gastaldi & Camerin, 2018; Camerin & Longato, 2021), which, on the contrary, promote interventions aimed at outdoor community sport – such as public parks, cycle paths, playgrounds - and contribute to enhancing the strategic role of public open spaces intended as 'common goods'. Horne (Horne, 2007) identifies a number of 'known unknowns' with respect to the SMEs that are part of the political debate on SMEs, such as: (i) the emphasis on consumption as opposed to the social balance goals stated in the applications of cities to the SMEs; (ii) urban redevelopment which often accelerates 'gentrification' processes; (iii) the spatial concentration of the impact of the event and the impact on the local community are some 'open questions' that require an interdisciplinary approach between transport and land-use planning for SMEs (Horne, 2021).

1.2 Stadium and Sport Mega Events.

By their nature, stadiums refer to sports entertainment and leisure time and are connected and interacting with the relative urban system to which they belong.

The match ritual typical of the traditional stadium has been replaced by the everyday life of the matches. With the progressive affirmation of the modern stadium, based on international standards, the match becomes part of everyday life. Analysing the modern stadium in the urban system to which it belongs and tracing tangible and intangible effects means studying shapes, spaces and spatial organization, but, above all, the relationships between communities, not only related to sport (Bennett, 2012).

As a result of the guidelines provided in the UEFA Guide to Quality Stadiums (2011), the Anglo-Saxon contamination started to widespread, so much so that new stadiums are conceived for both leisure and business. Furthermore, stadiums are able to activate urban gentrification, starting for that of the users (Tosi, 2016). In fact, associated with the stadium (especially urban) there is a conversion of public spaces to make them more attractive for consumers. The transport management during the SMEs requires careful planning of the mobility models of the urban area of reference, reconciling environmental sustainability with the need to guarantee the quality of life of the proximity local community. This implies the need for a major effort in transport planning and monitoring in host cities. In particular, the planning of the SMEs requires specific actions in order not to interfere with both Local Public Transport (LPT) and with the urban functions of the land use (Elagouz et al., 2022).

In this framework, which is also a result of the 'Sport city' research started in 2018 (Balletto et al., 2018), the objective of the manuscript is to build a synthetic index (PI) to support SMEs planning. In particular, the land use and accessibility are the main fields of investigation, together with the geographical and planning aspects of the case study (the new urban football stadium of Cagliari, Sardinia, Italy).

The manuscript is organized as follows.

Section 2 provides a literature review that focuses on the Italian stadium generation (Section 2.1) and the mobility planning (Section 2.2); Section 3 focuses on the materials and method, with particular attention to methodology (Section 3.1.1) and data (Section 3.1.2); stadium and study area (Section 3.2); Section 4 describes the application of the method to the case study; Section 5 discusses the results of the case study, while Section 6 contains the conclusion.

2. Stadium, sport city and mega events

2.1 Italian stadium generation.

The stadium was born as a 'sport events factory' and has developed thanks to, on the one hand, the evolution of sport and, on the other one, the progressive increase in the people’s affection towards sport, attracted by the desire to attend and participate in sporting events, in recent times also with the support of the sponsor and media link (Raco, 2012), following the development of the sport business industry (Riot et al., 2018). Stadiums are no longer just sport infrastructures but are configured as complex urban drivers (Balletto et al., 2021; Ladu et al., 2019). The stadium can therefore be conceived as a new '*central place*', of a private nature, and represents the outcome of a complex legislation on public works, associated with the objectives of the 2030 Agenda (Bausinger, 2013; McCullough et al., 2022).

In this framework, it is possible to highlight three main generations of Italian stadium:

- First generation – Suburban stadium (until the 80s of 20th Century). The location of stadiums was guided by the urban sprawl of the economic boom and a widespread euphoria in the real estate market;
- Second generation - Restyling of the 90s (Italian World Cup 1990). The World Cup of the 90s (of 20th Century) allowed for a profound renewal of the Italian stadiums (Milan, Turin, Verona, Udine, Genoa, Bologna, Florence, Rome, Naples, Bari, Palermo and Cagliari) also of the urban and transport infrastructures made necessary following the urban growth that gradually incorporated most of the stadiums;
- Third generation - Smart stadium (European Cup 2023). With the restyling proposed by the candidate cities (Milan, Turin, Verona, Genoa, Bologna, Florence, Rome, Naples, Bari, Cagliari and Palermo), actions have also been proposed to regenerate urban areas and transport infrastructures, aimed at activating relations with the local community and city users through services: transport, retail, sport and leisure (Kool, 2017) and multiple actions to reduce interference from SMEs (Aicher, 2017; Aicher et al, 2019). In fact, with the so-called Italian Stadium Law (Law Decree n. 50 24/4/2017), Italian stadiums are part

of a wider urban regeneration activity, also as a result of a renewed public-private relationship (Turner & Carnicelli, 2017).

Furthermore, the third generation of stadiums has also fostered digital transition which in turn created new impulses in the challenge of the European Cities of Sport, with the aim of influencing the well-being and health of local communities in the broader framework of the objectives of the 2030 Agenda (Saiu et al, 2022).

2.2 The mobility planning.

The assessment of accessibility and the related management of the flows of people and vehicles (LPT in particular) for SMEs stadiums constitutes an important challenge for the management of sustainable mobility (Elagouz et al., 2022) and the related containment of environmental interference (air , noise etc.), between safety and health (Mair et al., 2021). This is the object of particular attention by the Organizing Committees of Major Events, in the context of the wider competition between modes of transport. The assessment of accessibility for the various modes of transport is of fundamental importance to guarantee the success of sustainable mobility policies also in the SMEs and their mutual influence (Ballarano et al., 2022; Chirieleison et al., 2020). The complexity of assessing accessibility in fact derives from the need to take into consideration all the average times of the individual stages of the journey, also considering the time waste deriving from the interactions between the different flows (congestion levels) or from traffic regulation systems (speed limits, traffic lights, roundabouts, permitted or prohibited driving directions and turns, etc.). In this sense, this manuscript wants to develop an interdisciplinary approach based on LPT, which derives from the evolution of the stadium (from 2nd to 3rd generation). In fact, the complexity and sustainability objectives of third generation stadiums require that accessibility is guaranteed by LPT, also to reduce interference with the local community.

For this reason, the assessment of average accessibility therefore requires the aid of traffic models capable of representing:

- the public mobility demand (demand model) represented through the estimate of origin/destination matrices, the result of the estimate of the number of journeys potentially generated by the different areas of the territory on the basis of the settlement characteristics and the costs of the different alternatives of travel;
- the transport supply (supply model) through the construction of a network graph capable of representing the mobility infrastructures and their characteristics in terms of speed/travel times in conditions of free flow or congestion, capacity (maximum number of vehicles, passengers who can transit in an hourly interval, permitted directions, regulation of intersections-nodes, stops, priorities, roundabouts, traffic lights), LPT services (routes, stops and frequencies).
- the traffic flows (assignment model) through the interaction between the transport demand and the transport supply.

3. Materials and Method

The research carried on was aimed at considering together two aspects of urban planning and accessibility. Along with this, sport facilities – a football stadium in particular – were considered as an urban infrastructure and, more than that, integrated in a proximal space characterized by the existence of a set of other facilities and location dedicated to sport and leisure.

3.1 Methodology and Data

3.1.1 Methodology of Proximity Index (PI)

The method adopted is aimed at developing a Proximity Index (PI) to evaluate accessibility scenarios (ex-ante) combined with proximity (x min) land use of SMEs. In particular PI can be described with the following formula, which represents the weighted sum (1-n) of the ratio between cluster area (KDE) of land use and spatial proximity (x min).

$$PI = \frac{1}{n}\sum_{i=1}^{n} w_i k_i \qquad 0 \leq I \leq 1$$

where

$$k_i = \frac{cluster\ area\ of\ KDE_i}{spatial\ proximity} \qquad 0 \leq k_i \leq 1$$

In particular, the KDE_i area represents the area of the Kernel Density Estimation cluster of the i dateset. Spatial proximity is the buffer area (15-minute city). The weight w_i is a function of the different KDE_i accessibility classes and can be represented by the following formula.

$$w_i = \frac{\sum_{i=1}^{n} w_i \cdot accessibility\ area_i}{cluster\ area\ of\ KDE_i} \qquad 0 \leq w_i \leq 1$$

If PI = 0-0.25 it represents a critical scenario (level 4); if PI = 0.26-0.50 it represents an average critical scenario (level 3); PI = 0.5-0.75 it represents an average positive (level 2); if PI = 0.76-1 it represents a positive scenario. (level 1). To increase the level of the PI scenario, specific local LPT, walk, bike and sharing mobility actions are required.

The PI was developed considering, as the numerator, a combination of density estimates for different datasets – as below described -, representative of different phenomena, characteristics and services related to study area. The different phenomena are considered in terms of point locations, over which a density estimate is performed. Following previous studies (Kim & Scott, 2012; Borruso, 2008; Borruso & Porceddu, 2009) the scope is obtaining a continuous density estimate surface so that point - small areas are assigned a value that can be combined to obtain the punctual / small area numerator of the above introduced Index, as the cluster area of dataset (ID: 03.1 - 03.5 of the Table 2).

In particular, the KDE appears as a proficient instrument to transform a point pattern into a continuous density surface, by controlling a limited set of parameters. As in Bailey and Gatrell studies (Bailey & Gatrell, 1995), the kernel consists of a 'moving three dimensional function that weights events within its sphere of influence according to their distance from the point at which the intensity is being estimated.

$$\hat{\lambda}(s) = \sum_{i=1}^{n} \frac{1}{\tau^2} k\left(\frac{s - s_i}{\tau}\right)$$

Where, λ(s) is the estimate of the intensity of the spatial point pattern measured at location s, s_i the observed i-th event, k() represents the kernel weighting function and τ is the bandwidth (Fig. 1).

For two-dimensional data the estimate of the intensity is given by:

$$\hat{\lambda}(s) = \sum_{d_i \le \tau}^{n} \frac{3}{\pi\tau^2}\left(1 - \frac{d_i^2}{\tau}\right)^2$$

Where, d_i is the distance between the location s and the observed event point s_i. The kernel values therefore span from $\frac{3}{\pi\tau^2}$, at the location s to zero (0) at distance τ.

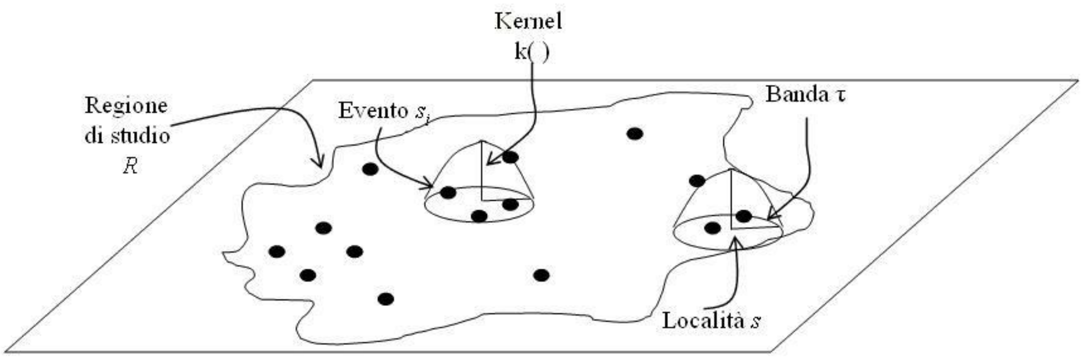

Figure 1: Kernel Density Estimation quadratic (KDE). Elaboration in Borruso (2003).

A quadratic KDE was used, with a 500 m bandwidth and 25 m cell-size. The 25 m cell represents a discrete approximation of the continuous density estimation surface and can be considered as the location of a general location s. Such a dimension was considered useful also for attributing other values as coming from other indicators in the summarization of the different values assigned. The selected 500m bandwidth was considered useful and suitable for this scale of analysis, as performed in other similar studies and, particularly, in terms of a 5-10 minutes walkability.

3.1.2 The Data

According to the literature review (Section 2), a dataset is proposed, as summarised in (Table 1):

Table 1: Datasets.

ID	*Dataset*	*Open Data*	*Data Source*
01	Traffic Model of Metropolitan city	✗	Mlab.srl, 2022
02	Walk and Bike heatmap layer	✓	Strava, 2022
03	Urban Atlas (Land-use)	✓	Urban Atlas, 2018 Edition
03.1	Sports and leisure facilities		
03.2	Continuous urban fabric (SL>80%)		
03.3	Discontinuous dense and medium density urban fabric (SL 50-80%)		
03.4	Discontinuous medium and low density urban fabric (10-50%)		
03.5	Industrial, commercial public, military and private units		

In particular the dataset consists of different layers:

01. Traffic Model of Metropolitan city of Cagliari (Sardinia). As part of the study of the Metropolitan City of Cagliari, a traffic model was developed as a support to various mobility studies and plans (Urban Mobility Plan, Minimum Services Plan, Feasibility

Studies of the new tramway network) and to evaluate the level of accessibility for approximately 780 traffic zones into which the territory of the Metropolitan City of Cagliari has been divided. The model is able to evaluate the itineraries between all the origin-destination (O/D) pairs and the relative travel times;

02. Walk and Bike heatmap layer. The Global Heatmap shows the concentration of publicly available activities by users as performed in the past year. The Global Heatmap is provided by the popular app and web services Strava, collecting tracks and traces by users, grouped and classified according to the different sport's activities in which they were involved;

03. Urban Atlas. Copernicus Urban Atlas (2018 edition). Particularly it was selected a subset of the available spatial information as in the atlas, a more refined and detailed classification of Land Cover / Land Use, organised in terms of Functional Urban Areas (FUA), street tree layer produced within the level 1 urban mask for each FUA, population estimates per Urban Atlas polygons and building block height in cities in a 10 x 10 m grid. The FUA - Copernicus Urban Atlas layer was used in particular to extract data related to the urban fabric and related population estimates attributed to such areas. That allowed overcoming a limitation given by the lack of availability of updated population data for Italy at census district level. The current and ongoing reorganisation of the official population data collection for Italy is in fact, at present, not providing population data at the most detailed level, as address point or census units, so the only available official sources were ISTAT 2011 census population data at census unit level. The Copernicus Urban Atlas, in such a sense, allows filling the gap, providing an estimate for population in 2018 per land use unit. Land use units' centroids were used for attributing population data and for performing the density analysis.

3.2 The Study Area. The city of Cagliari and the Cagliari Stadium (Cagliari, Italy)

The study area is represented by the metropolitan city of Cagliari, the major city and capital of Sardinia Region, identified as Metropolitan City since 2016. It is the most important cultural, economic, political and administrative centre of Sardinia, one of the autonomous Regions in the Italian first sub-national administrative subdivision. The Metropolitan City represents an administrative level including 17 municipalities, centred on the Municipality of Cagliari which, alone, hosts around 150,000 inhabitants, while the Metropolitan City hosts nearly 420,000 inhabitants (ISTAT, 2022), a quarter of the overall population of the Island (Table 2).

Table 2: Cagliari - Summary demographic statistics.

Cagliari	*Population (2022)*	*N. of Municipalities*
Municipality	148 881	1
Metropolitan City	419 770	17
Cagliari + South Sardinia	754 878	124

Our elaboration on data from ISTAT (2022)

Among the functions played by the city of Cagliari, the provision of services, particularly with reference to the present case, those related to sport and leisure, which in 2018 made it possible to win the European city of sport award.

In this context, a particular attention is paid especially on sport facilities and infrastructure cluster situated on the Southern districts of the Municipality of Cagliari where the old Sant'Elia Stadium is located and where the new Cagliari Stadium will be realized which forms the basis of the potential audience of the stadium, with a capacity of around 25,000 that can be expanded to 30,000 in the event of a match in 2032 for the European Championship.

The area appears particularly important and interesting from different points of view that can be summarised as follows:

- it represents an urban hinge between the Cagliari central area with the sea-side promenade, the Sant'Elia low-income neighbourhood and other residential neighbourhoods, together with access to the shores of Poetto beach;
- it is at the centre of important projects of urban redevelopment favouring the hinge between different parts of the city;
- it presents a concentration of residentials and facilities (public and private urban fabrics) and former military facilities earmarked for divestment, redevelopment, and urban investment, including the Stadium, the former Trade Fair and a set of military installations and compound to be partially opened to public use;
- it hosts a number of sport and leisure-related activities, from the football stadium to the basketball arena, together with other indoor and out-door activities, including, among others, swimming, rowing and sailing clubs;
- it represents an important transport connection within the Metropolitan City and between the city and its hinterland.

4. Case study

The planning of SMEs from an urban and mobility point of view is a challenge also for managing negative externalities: traffic, pollution, noise, safety for the local community Balletto et al., 2022).

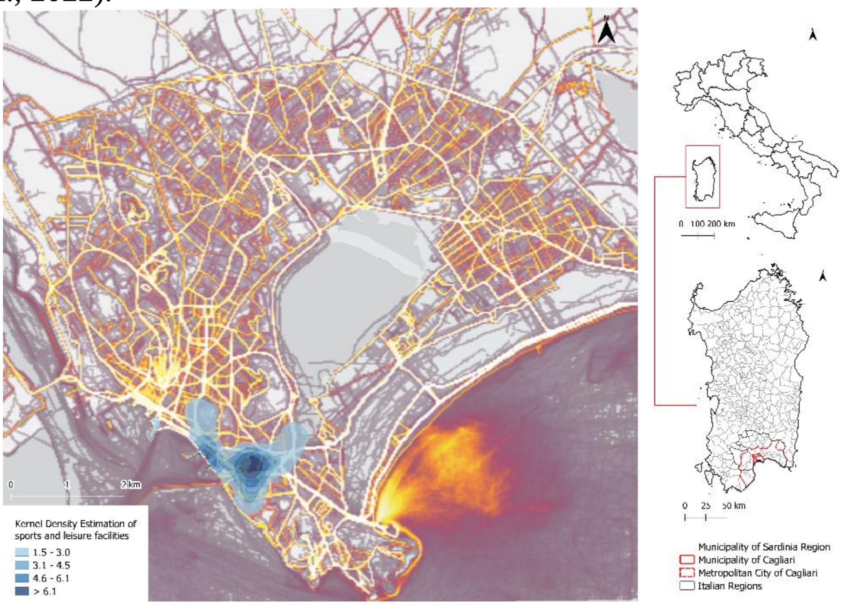

Figure 2: Sports and leisure facilities and walk and bike heatmap layer (Authors: Balletto G. and Sinatra M., 2022)

Cagliari city, with the construction of the new stadium, is a candidate to host the 2032 European Championship. Cagliari city plays a role as the major urban area in the island, as the headquarters for the most important sports infrastructures. For this reason, the new stadium was selected as a case study.

In particular, in the south of Cagliari it is possible to register two sport clusters that can be associated by Walk and Bike heatmap layer (Ladu et al., 2019), (Figure 2).

Figure 2 shows the results obtained from the use of the quadratic KDE with a 500 m bandwidth on the dataset - ID: 3.01 (Table 2)- sport and leisure facilities, visualised using cell junctions with 25 m spacing (Borruso, 2003) on walk and bike heatmap layer (ID 02 - table 2) (Global Heatmap - Strava website).

The geospatial representations of the respective Kernel Density Estimations of the dataset proposed (ID 03 table 2) by the associated LPT accessibility are shown, with spatial proximity (R=1500 m) from the stadium highlighted:

- sports and leisure facilities, (Figure 3);
- continuous urban fabric (SL>80%), (Figure 4);
- discontinuous dense and medium density urban fabric (SL 50-80%), (Figure 5);
- discontinuous medium and low density urban fabric (10-50%), (Figure 6);
- industrial, commercial public, military and private units, (Figure 7).

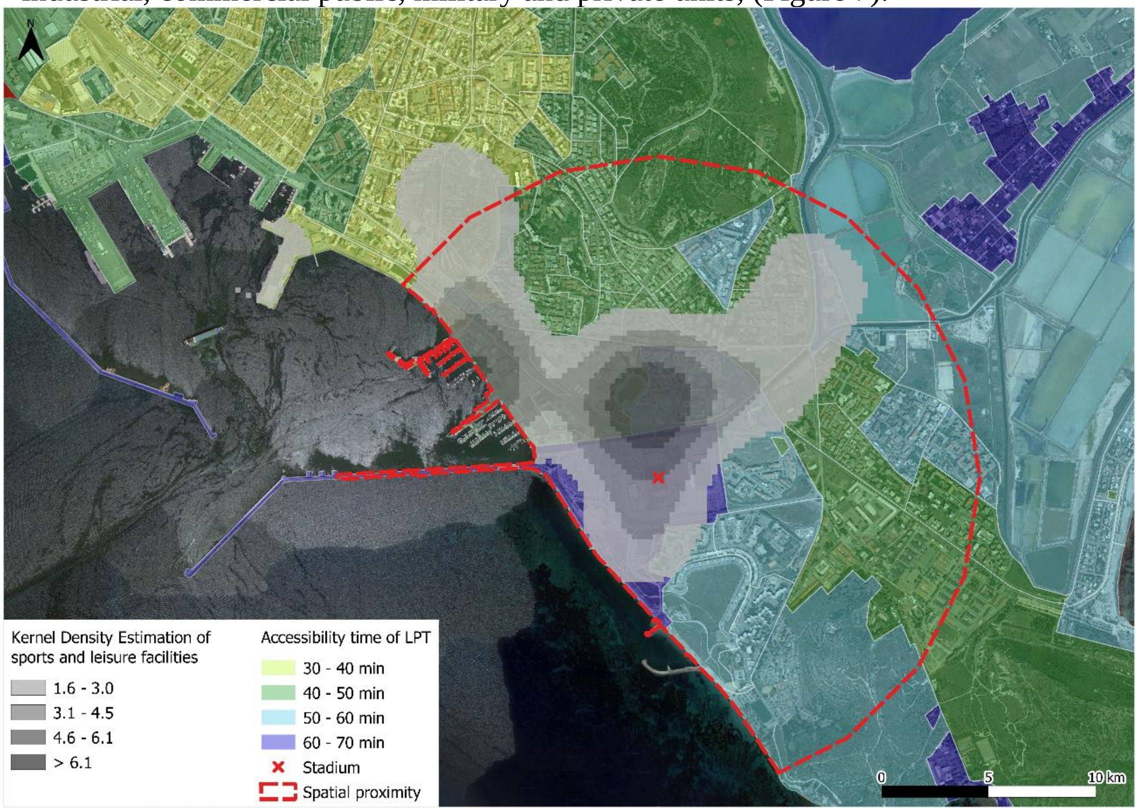

Figure 3: Kernel Density Estimation of sports and leisure facilities and accessibility of LPT (Authors: Balletto G. and Sinatra M., 2022).

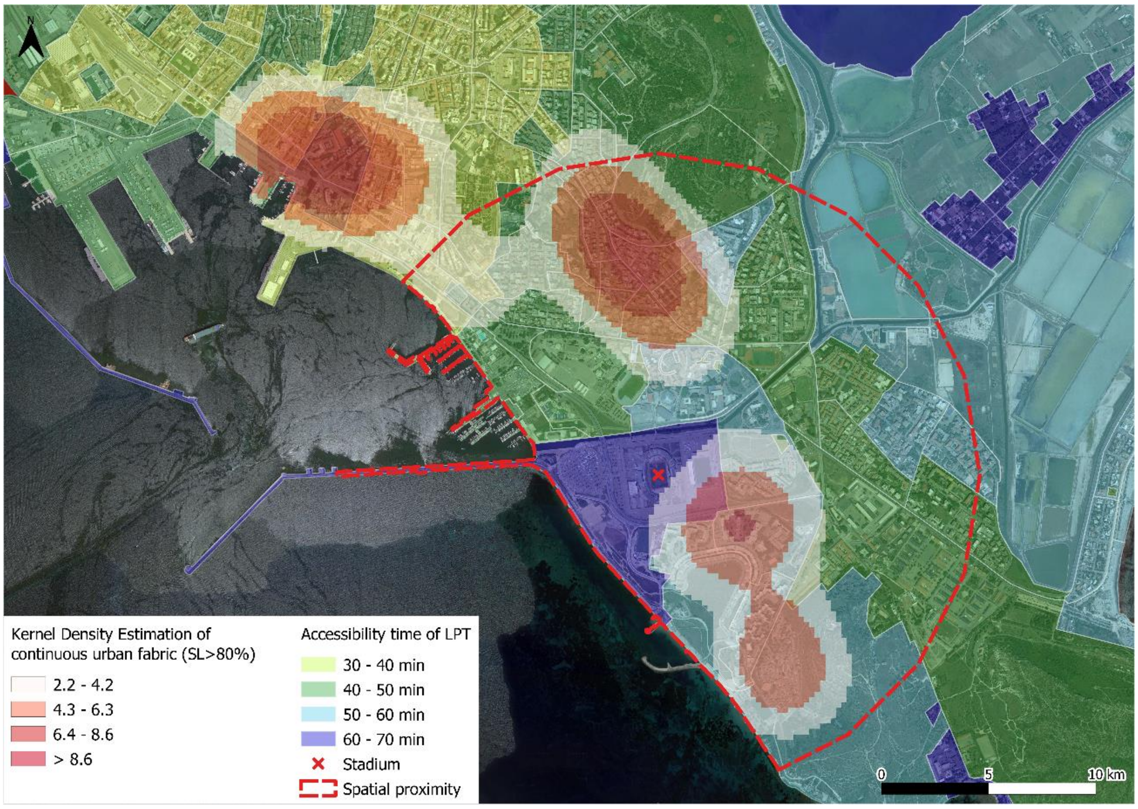

Figure 4: Kernel Density Estimation of Continuous urban fabric (SL>80%) and accessibility of LPT (Authors: Balletto G. and Sinatra M., 2022).

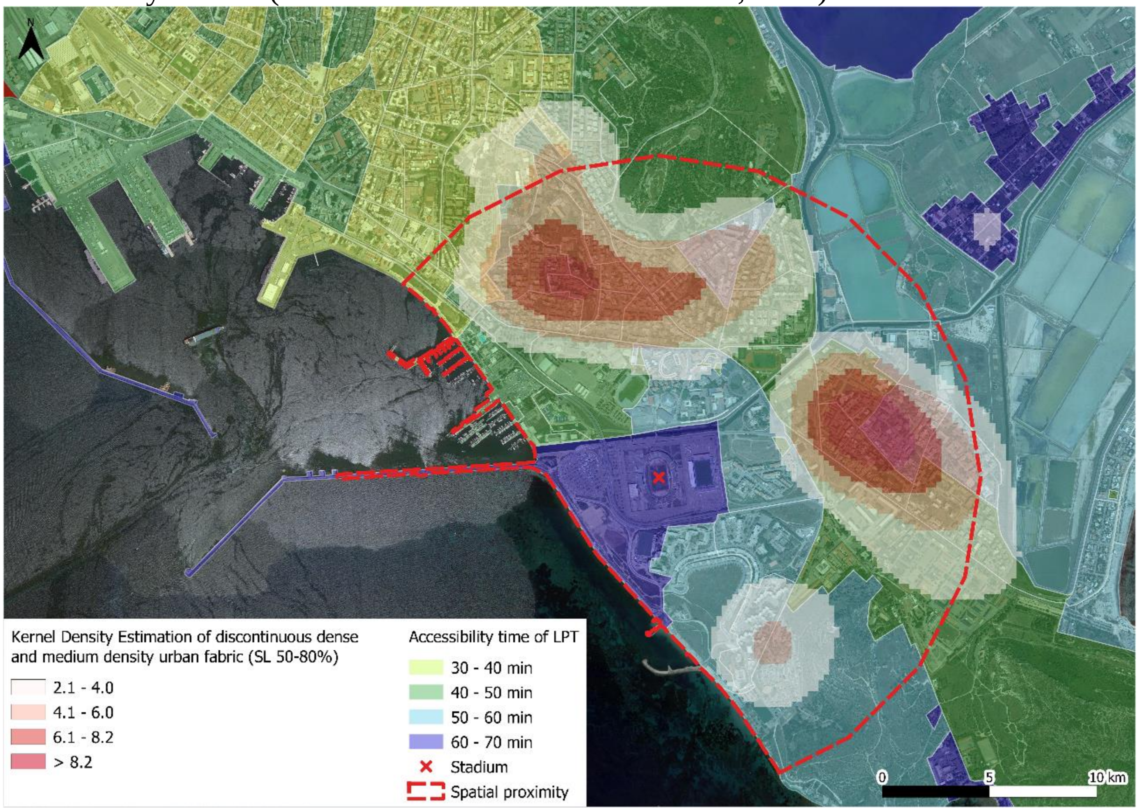

Figure 5: Kernel Density Estimation of discontinuous dense and medium density urban fabric (SL 50-80%) and spatial proximity of the stadium (Authors: Balletto G. and Sinatra M., 2022).

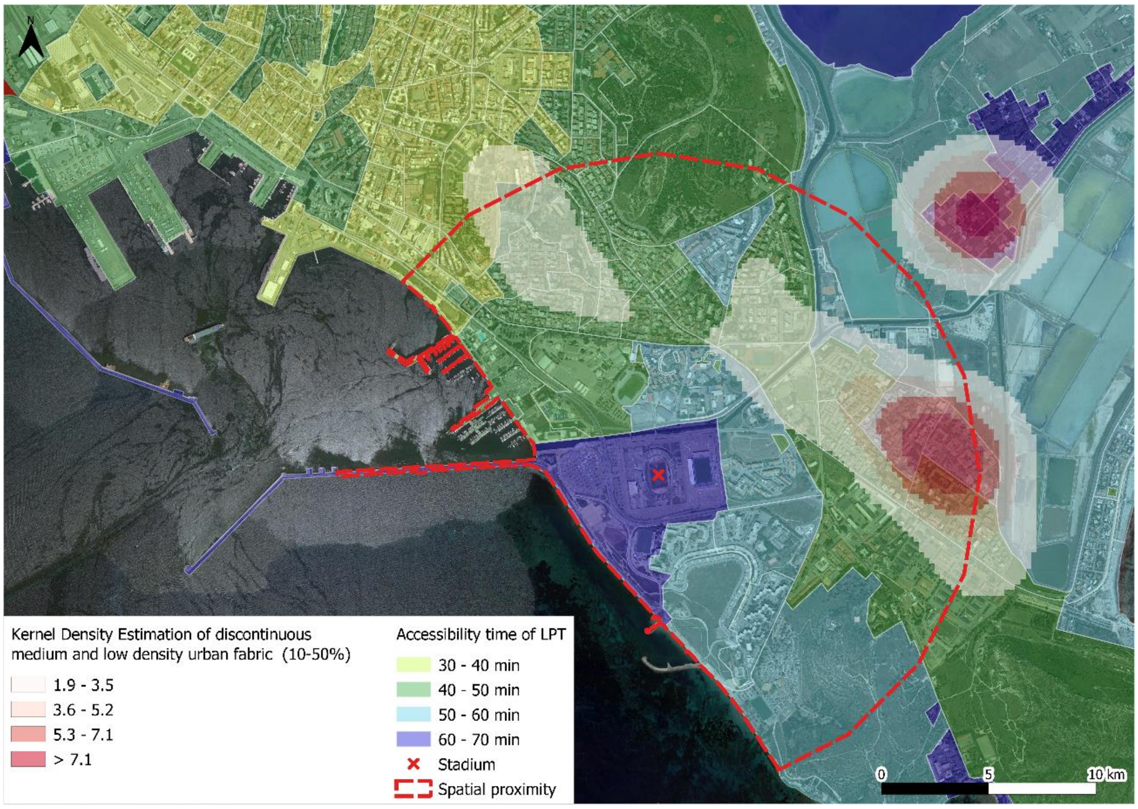

Figure 6: Kernel Density Estimation of discontinuous medium and low density urban fabric (10-50%) and accessibility of LPT (Authors: Balletto G. and Sinatra M., 2022).

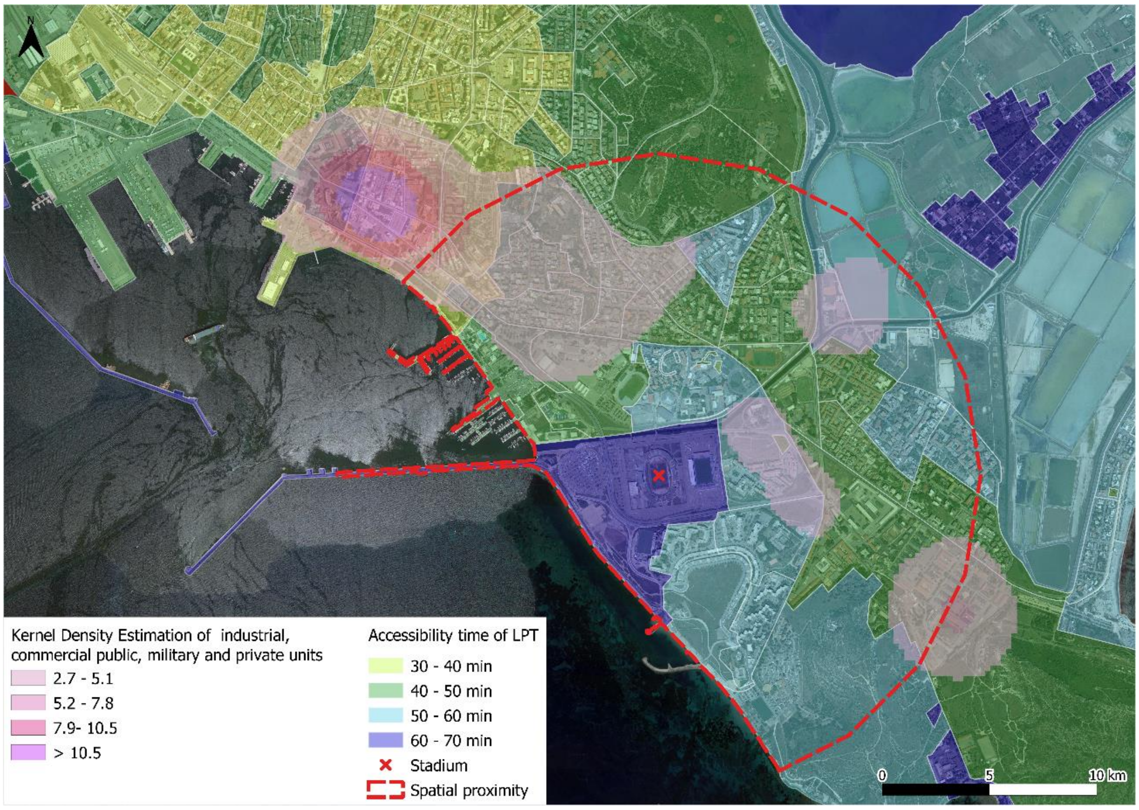

Figure 7: Kernel Density Estimation of industrial, commercial public, military and private units and accessibility of LPT (Authors: Balletto G. and Sinatra M., 2022)

5. Results and Discussions

Following the literature review this study proposes a quantitative methodology to build a synthetic index (PI) to support decisions on SMEs.

According to the proposed approach, the PI is applied to the Cagliari stadium and its spatial proximity to evaluate the ex-ante scenario.

The evaluation of the PI refers to spatial proximity (4,670,000 m^2) of stadium and in particular five clusters (fig-3-7) developed through the KDE.

The research hereby carried on represented a testbed for analysing the SMEs in the context in which they are inserted, combining their location and their 'spatial proximity' from different points of view, such as urban planning, as well as planning transport, with particular reference to accessibility. The novelty of the approach stand in the combination of the concept of proximity with methods (KDE), tools (GIS), and planning indicators (dataset proposal, table 2). The research was based on the concept of spatial proximity, i.e. the consideration of a "buffer - service area" around the new stadium. Such an area - dashed red line in Figures 3 - 7 - represents, potentially, a 'sport & leisure neighbourhood', in the plans of the Municipality of Cagliari of redevelopment of the area, where sport activities and facilities play an important role in shaping the supply of services over a wider, neighbouring area. Such a mix of function and characteristics is summarized in Table 3, where the results of the analyses performed in the area are presented. The proximity index derived presents some low values, attributable to the low accessibility so far characterizing the area. In particular, the PI represents to the ex ante scenario of a critical type (level 4) which requires significant LPT and urban design actions to encourage cycle-pedestrianism. These are actions on a metropolitan and local scale without which the SMEs would produce significant interference in the local and metropolitan community.

Table 3: Summary of the results.

Cluster (Kernel Density Estimation)	w_i	*Cluster area of KDE (m^2)*	*Ki*
Sports and leisure facilities	0.60	1 705 563	0.37
Continuous urban fabric (SL>80%)	0.62	1 485 586	0.35
Discontinuous dense and medium density urban fabric (SL 50-80%	0.69	2 023 436	0.43
Discontinuous medium and low density urban fabric (10-50%)	0.61	1 640 823	0.32
Industrial, commercial public, military and private units	0.70	1 381 654	0.30
PI (scenario ex-ante) = 0.23 (level 4)			

Source: our elaboration.

Overlaying, in fact, the results of the intermediate indicators, then merging into the PI, it appears as the area presents interesting potential in appearing central for both peak match days and off-peak, ordinary sport & leisure activities. The accessibility analysis performed on the Municipality of Cagliari shows, in particular, a lack of accessibility in the area, which at present represents the major drawback and limitation, particularly as the stadium area, as pointed out in the paper, is located in a semi-central location and not in an out-of-town one. The development and implementation of public transport - light transit system, extension of the bus network, etc. - represent a necessary solution in order to reduce car-dependency and develop a neighbourhood with the sustainable city - and the 15 minutes city - in mind. In this sense, the PI makes it possible to develop comparative assessments between scenarios (ex ante - ex post), thus allowing it to support planning decisions.

6. Conclusions and future work

The interdisciplinary approach followed in the present research aims to develop the proximity index of SMEs. A multi-layered interdisciplinary approach was in fact adopted, combining the principles of the sustainable city - in its more recent evolutions towards the 15-minute city - from different points of view. As discussed above, the focus in the present paper has been on the proximity area of the planned new football stadium and relative mega events, realized drawing an approximately 15 minute buffer zone around the stadium and overlaying on that different density analysis on residential, activities and services, as well as accessibility from the transport planning point of view. This was realized using different spatial analytical techniques, allowing gridding the study area, allowing obtaining a minimal unit of analysis where the results from the different partial indicators can be referred to.

As described, in the present research a minimum unit of 25m was used to collect and represent the results. The aim for future research is continue in this line to better exploit the model, adapting the realization of the density analysis over a network environment, therefore considering the density of phenomena over a transport network structure, and at the same time considering from the same point of view the computation of the buffer-zone proximity area. That would allow a more realistic computation and consideration of the urban spaces, also allowing differentiated analyses, from the accessibility point of view, according to the different uses of the networks, including in the computation, alternatively, therefore, those of pedestrian movement, the public transport one, and the private one.

In addition, it is intended to implement the dataset. In particular, the evaluation of a specific dataset related to digital connection will also be in the future research work, in line with the recent approach of Triple Access Planning (TAP), which, is based on urban accessibility, that can be achieved through the transport system (physical mobility), the territorial system (spatial proximity) and the telecommunications system (digital connectivity). Digital connectivity, i.e. being connected, has in fact become an integral part of daily life, as important for communities and businesses as connection to primary service networks (water, gas, electricity, transport) and therefore relevant in urban planning.

References

Aicher R. (2017) Football stadiums and urban development. Do they provide more for the city than just the classical 'bread and circuses'? A study into the impact of football stadiums in the Dutch context. Master thesis, Radboud University, Nijmegen.

Aicher T. J., Paule-Koba A. L., Newland B. (2019) Sport facility and event management, Jones & Bartlett Publishers.

Bailey, T. C., & Gatrell, A. C. (1995) "Interactive spatial data analysis", 413, No. 8, Essex: Longman Scientific & Technical.

Ballarano, D., Patella, S. M., & Asdrubali, F. (2022) "Sustainable Transportation for Events: A Systematic Review", Sustainability, 14(23), 15815.

Balletto, G., Borruso, G., Tajani, F., & Torre, C. M. (2018), "Gentrification and sport. Football stadiums and changes in the urban rent", in International Conference on Computational Science and Its Applications, pp. 58-74, Springer, Cham.

Balletto, G., Ladu, M., Camerin, F., Ghiani, E., & Torriti, J. (2022) "More circular city in the energy and ecological transition: a methodological approach to sustainable urban regeneration", Sustainability, 14(22), 14995.

Balletto, G., Borruso, G., Milesi, A., Ladu, M., Castiglia, P., Dettori, M., & Arghittu, A. (2021) "Sport-City Planning. A Proposal for an Index to Support Decision-Making Practice: Principles and Strategies", In International Conference on Computational Science and Its Applications, pp. 255-269, Springer, Cham

Balletto, G., Ladu, M., & Camerin, F. (2022) "Sustainable Urban Mobility Planning and Walkability in the Post Pandemic era. Assessing the Role of Urban Enclaves", in International Conference on Computational Science and Its Applications, pp. 257-266, Springer, Cham.

Balletto, G., Ladu, M., Milesi, A., Camerin, F., & Borruso, G. (2022) "Walkable City and Military Enclaves: Analysis and Decision-Making Approach to Support the Proximity Connection in Urban Regeneration", Sustainability, 14(1), pp. 457.

Barbosa, A., Vallecillo, S., Baranzelli, C., Jacobs-Crisioni, C., Batista e Silva, F., Perpiña-Castillo, C., Lavalle, C. & Maes, J. (2017) "Modelling built-up land take in Europe to 2020: An assessment of the Resource Efficiency Roadmap measure on land", Journal of Environmental Planning and Management 60(8), pp. 1439-1463.

Bausinger, H. (2013) La cultura dello sport, Armando Editore.

Bennett J. T. (2012) "They Play, You Pay: Why Taxpayers Build Ballparks, Stadiums, and Arenas for Billionaire Owners and Millionaire Players", Springer, New York.

Borruso, G. (2003), "Network density and the delimitation of urban areas". Transactions in GIS, 7(2), pp. 177-191.

Borruso, G. (2008) A GIS Approach for Analysing Point Patterns in a Network Space, Transactions in GIS, 12(3), pp. 377-402.

Borruso, G., Porceddu, A. (2009). A Tale of Two Cities: Density Analysis of CBD on Two Midsize Urban Areas in Northeastern Italy. In: Murgante, B., Borruso, G., Lapucci, A. (eds) Geocomputation and Urban Planning. Studies in Computational Intelligence, vol 176. Springer, Berlin, Heidelberg

Camerin, F., & Longato, D. (2021) "Urban impacts of Spain 1982 and Italy 1990 FIFA World Cup: a comparative analysis with more recent sports mega-events", Urban Research & Practice, pp. 1-18.

Chirieleison, C., Montrone, A., & Scrucca, L. (2020), "Event sustainability and sustainable transportation: a positive reciprocal influence", Journal of Sustainable Tourism, 28(2), pp. 240-262.

Elagouz, N., Onat, N. C., Kucukvar, M., Sen, B., Kutty, A. A., Kagawa, S., Nansaie K. & Kim, D. (2022) "Rethinking mobility strategies for mega-sporting events: A global multiregional input-output-based hybrid life cycle sustainability assessment of alternative fuel bus technologies", Sustainable Production and Consumption, 33, pp. 767-787.

Gastaldi, F., & Camerin, F. (2018) "Transformaciones urbanas y grandes eventos en Italia y España a partir de 1992", Estudios territoriales, 50(196), ISSN: 1133-4762.

Horne, J. (2007) “The four ‘knows’ of sport mega-events”. Leisure Studies. 26 (1), pp. 81-96.
Horne, J. (2021) “Sports mega-events”, in Research Handbook on Sports and Society Edward Elgar Publishing, pp. 128-142.
Kenyon, S., & Lyons, G. (2007) “Introducing multitasking to the study of travel and ICT: Examining its extent and assessing its potential importance”, Transportation Research Part A: Policy and Practice, 41(2), pp. 161-175.
Kim, J., & Scott, C. D. (2012), “Robust kernel density estimation”, The Journal of Machine Learning Research, 13(1), pp. 2529-2565.
Ladu, M., Balletto, G., & Borruso, G. (2019) “Sport and smart communities. Assessing the sporting attractiveness and community perceptions of Cagliari (Sardinia, Italy)”, in International Conference on Computational Science and Its Applications, pp. 200-215, Springer, Cham.
Mair, J., Chien, P. M., Kelly, S. J., & Derrington, S. (2021), “Social impacts of mega-events: A systematic narrative review and research agenda”, Journal of Sustainable Tourism, pp. 1-22.
McCullough, B. P., Kellison, T., & Melton, E. N. (Eds.), (2022) The Routledge Handbook of Sport and Sustainable Development, Routledge.
Raco M. (2012) “The privatisation of urban development and the London Olympics 2012”, City, 16(4), pp. 452-460.
Riot, C., Kennelly, M., Hill, B., & Trenberth, L. (2018) “The sport business industry in the twenty-first century”, in Managing Sport Business, pp. 3-21, Routledge.
Romano, B., Zullo, F., Fiorini, L., Marucci, A., & Ciabò, S. (2017) “Land transformation of Italy due to half a century of urbanization”, Land use policy, 67, pp. 387-400.
Russo, F. (2022) “Sustainable Mobility as a Service: Dynamic models for agenda 2030 policies”, Information, 13(8), pp. 355.
Saiu, V., Blečić, I., & Meloni, I. (2022) “Making sustainability development goals (SDGs) operational at suburban level: Potentials and limitations of neighbourhood sustainability assessment tools”, Environmental Impact Assessment Review, 96, 106845.
Tosi S. (2016) “Le politiche urbane e gli stadi”, in La rivista delle politiche sociali, n. 1, pp. 151-162.
Turner, D., & Carnicelli, S. (Eds.) (2017) Lifestyle sports and public policy, Routledge, Taylor & Francis Group.
CONI website: https://www.coni.it/it/impianti/norme-e-regolamenti.html (16/01/2023)
Earth Overshoot Day website: https://www.overshootday.org/newsroom/country-overshoot-days/ (16/01/2023)
Global Heatmap - Strava website: https://www.strava.com/heatmap#7.00/-120.90000/38.36000/hot/all (05/12/2022)
TAP website:_ https://www.tapforuncertainty.eu/ (19/01/2023)

Author Contributions

Conceptualization, methodology, formal analysis, materials and resources, software and data curation: Balletto, Borruso and Sinatra. Validation: all authors. In particular: Balletto and Sinatra wrote Section 1; Balletto wrote Section 2.1, Section 3.2.1, Section 4; Balletto and Borruso wrote Section 3.2.2; Meloni, Fancello and Sechi wrote Section 2.2; Borruso wrote Section 3.1 and Section 5; Balletto, Borruso and Fancello wrote Section 6. All authors have read and agreed to the published version of the manuscript.

Acknowledgements

Part of the research activity presented in this paper by authors was developed within the following:

- Interdepartmental Center of the University of Cagliari “Cagliari Accessibility Lab” https://sites.unica.it/cal/, Laboratory of Political Economic Geography of the University of Trieste “GEP LAB” http://www.labgeonet.it/it/gep-lab/ and Jane’s Walk Festival. Balletto Ginevra (Cagliari City organizer).

- The project ‘Sport city’ (2018-2021) which includes the case of the new Cagliari stadium in partnership with the DICAAR (Department of Civil Environmental Engineering and Architecture, University of Cagliari - Balletto Ginevra PI for the themes of the landscape, the environment and the circular economy;

- This publication was produced while attending the PhD programme in Civil Engineering and Architecture at the University of Cagliari, Cycle XXXVIII, with the support of a scholarship co-financed by the Ministerial Decree no. 352 of 9th April 2022, based on the NRRP - funded by the European Union - NextGenerationEU - Mission 4 "Education and Research", Component 2 "From Research to Business", Investment 3.3, and by the company MLab srl;

- Minimum Service Plan of the Local Public Transport in the Metropolitan City of Cagliari (Sardinia, Italy), in progress, CUP J43D18000120001. Mlab srl (Ing. Francesco Sechi PI).