Journal of Civil Engineering and Architecture 14 (2020) 409-426
doi: 10.17265/1934-7359/2020.08.001

Planning Sports Facilities Based on a Multicriteria Model Built in GIS Environment

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Abstract: The objective of this work is to evaluate the coverage of the sports facilities at Oeiras Municipality, near Lisbon, in Portugal, identifying the well-served areas and those with deficit coverage, according to the national norms for sports facilities programming and characterization, based on a self methodology, in a geographic information system (GIS) environment. For the deficit covered areas, a multicriteria analysis was developed, based on the established national criteria, which allow the identification and prioritization of interventioned areas for sports facilities. The results obtained by the application of this tool enable more informed and more detailed knowledge of the Oeiras Municipality sports supply, providing essential information for decision making in the planning of sports facilities.

Key words: Service area, spatial coverage, sports facilities planning, multicriteria analysis, decision models, GIS.

1. Introduction

The determination of sports facilities service areas (SFSA) is aimed at assessing the levels of spatial coverage of these facilities, in order to obtain technical information that allows the development of more well-founded local sports policies. Identifying spatially well-served areas and areas of deficit coverage (ADC), the local administration planning services have insider information for decision making in both the new location of equipment and the management of the existing ones. The knowledge of spatial coverage levels, by type of sports facilities (SF), is another fundamental tool for sports planning demand that is intended to be diversified and to serve the various population strata, allowing a suitable allocation of supply in the territory.

The objective of this study is to evaluate the coverage levels of the Oeiras Municipality sports facilities, using available national criteria, identifying areas of good and poor coverage and proposing intervention areas for the installation of new SFs, based on a multicriteria model of decision support.

In order to determining the levels of spatial SFs coverage, we developed a mathematical model in a GIS environment that translate to the pedestrian movement incorporating the friction of the slope and the architectural features of the public space. In order to determine the priority levels for SFs installation, in deficit coverage areas, we adopted a multicriteria model based on the Portuguese Directorate-General for Territorial Planning criteria, which allows us to have a decision support tool in the sports facilities programming [1].

2. Methodology for Sports Facilities Service Areas Calculation

On our searches on the internet, no relevant references were found on criteria and methodologies for calculating service areas for sports facilities applied at the municipal level. For the present study we emphasize the reading of the following publications:

- CMO. 2005. *Map of Sports at Municipality of Oeiras*. C. M. Oeiras, ed. [2].

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• CMO. 2010. *Map of Sports Municipality of Cascais*. C. M. Oeiras, ed. [3].

• DGOTDU. 2002. *Rules for the Programming and Characterization of Sports Facilities*. Lisbon: DGOTDU [5].

The actual national rules for sports facilities only concern to criteria for the characterization and programming of Basic-Formative Sports Facilities (see Table 2).

The remaining types of SFs still go on with no regulation or rules, thus a request was made to the IPDJ—Portuguese Institute of Sports and Youth in order to programming criteria definition for Recreational Sports Facilities, but no answer was obtained during the project execution period. So, we had taken the audacity to establish criteria for them in this essay.

Given the particular nature of the Specialized or Monodisciplinary Sports Facilities (MSF) and the Special Sports Facilities for the Sports Show (SSFSS), the levels of coverage were not determined for them, since their spatial comprehensiveness should be understood in a supra-municipal perspective or regional level, being the central administration's responsibility for programming.

The methodology for sports facilities service areas (SSA) calculation considered in the present study and published at the International Seminar AESOP-2017 [4], is based on a multicriteria approach to generation of a friction surface, of pedestrian movement, in network, due to the roughness of the terrain and the architectural public space features. Thus, on the surface of generated friction, while obeying the laws of classical mechanics for the determination of velocity and time, the cost distances are not Euclidean. The main methodological steps considered to calculate sports facilities service areas are summed up in the following:

(1) Update of the spatial location and reclassification of the SFs;

(2) Determination of a friction surface based on cost-distance;

(3) Generation sports facilities service areas using DGOTDU irradiation criteria;

(4) Determination of the priority areas of intervention from areas of poor spatial coverage, using a multicriteria decision support model.

Next, each methodological phase will be analysed in detail.

2.1 Classification and Update of the Location of Sports Facilities

According to the legal sports facilities for public use regime, established by the Decree-Law No. 141/2009, of June 16st, sports facilities are defined as the built space or set of spaces resulting from fixed and permanent construction, organized for sports activities practice, which include areas to sports practice and the adjoining areas for support services and supplementary facilities [6].

There are not included in the actual legal sports facilities regime areas for specific use and integrated in: military barracks and enclosures, private security forces, prisons and thermal establishments, and health and rehabilitation units under medical and sanitary supervision [6].

The sports facilities are classified, by the same law, according to the following types:

(1) Basic Sports Facilities, which are subdivided into Recreational Facilities and Training Facilities;

(2) Specialized or Monodisciplinary Sports Facilities;

(3) Special Sports Facilities for the Sport Show.

The Base-Recreational Sports Facilities (B-RSF) comprise those that are intended for sporting activities with an informal character or without being subject to mandatory and permanent rules, in the context of recreational, maintenance and active leisure activities [6] (Table 2).

The Basic Sports Training Facilities (BTF) are designed for basic sporting and propaedeutic activities of access to specialized sports subjects for

Table 1 Characterization of basic sport facilities-formative.

Types of sports facilities	Range	Base population	Programming criteria		Sizing criteria			
	km on foot; minutes by public transports	Minimum inhabitants	ADU/in hab	ARU/in hab	ADU_rd (m^2)	ADU_st (m^2)	AI	ARU
Large playing field	2 a 3; 15 a 20	2,500	2	3	5,000	8,000	1.5 × ADU	1 × AI
Small playing field	0.5 a 1; 5	800	1	1.4	800	1,500	1.4 × ADU	1 × AI
Athletics track	2 a 4; 15 a 20	7,500	0.8	1.2	6,000	14,000	1.5 × ADU	1 × AI
Sports pavilions and sports halls	2 a 4; 15 a 30	3,000	0.15	0.48	450	1,350	1.6 × ADU	2 × AI
Indoor swimming pools	2 a 4; 15 a 30	5,000	0.03	0.24	150	400	4 × ADU	2 × AI
Outdoor swimming pools	2 a 3; 15 a 20	7,500	0.02	0.25	150	500	5 × ADU	2.5 × AI

Source: Ref. [5].

ADU: provision of useful sports area;

ADU_rd: provision of useful sports reduced area;

ADU_st: provision of useful sports standard area;

ARU: urban reserved area;

AI: implantation area.

Table 2 Basic, recreational and formative sports facilities (BTF).

Typologies	Subtypologies	Codification	Description
Base basic sports faciliteis	Recreational sports facilities	62a	Enclosures, courtyards, minicamps and elementary spaces destined to the initiation to the sports games, the traditional games and the physical exercises.
		62b	Permanent spaces and courses organized and designed for the free evolution, races or maintenance exercises, including the use of skates or recreational bicycles.
		62c	Open rooms and enclosures, with practice area of free dimensions, for activities of maintenance, leisure, recreational games, table games and uncoded sports games.
		62d	Indoor or outdoor swimming pools, of configuration and free dimensions, for recreational, leisure and maintenance uses.
	Sports facilities for training	72a	Large fields for football, rugby and field hockey.
		72b	Athletics tracks, closed-loop, outdoor and with regulatory tracing.
		72c	Sports halls and multipurpose sport halls.
		72d	Small fields, multi-sports fields, tennis courts and skating rinks, outdoors or with simple coverage.
		72e	Outdoor or indoor swimming for learning and multipurpose sports.

improvement and sports training, whose functional, constructive and multi-purpose characteristics are adjusted to the requirements deriving from the sports rules that fit the sports modalities for which they are created [6] (Table 2).

The spatial distribution of the Formative and Recreational Sports Facilities can be visualized in the following maps (Figs. 1 and 2).

The Specialized or Monodisciplinary Sports Facilities (S/MSF) are the permanent facilities designed and organized for the practice of single-disciplinary sports activities, as a result of their specific adaptation to the corresponding modality or the existence of natural conditions of the place and directed to the training and the training of the respective subject [6] (Table 3).

The Special Sports Facilities for the Sports Show (SSFSS) are permanent facilities designed to host sports competitions, and where a combination of factors such as the ability to receive the public and host the media is combined; the prevalent use in competitions and events with high levels of performance and the incorporation of significant and specific material

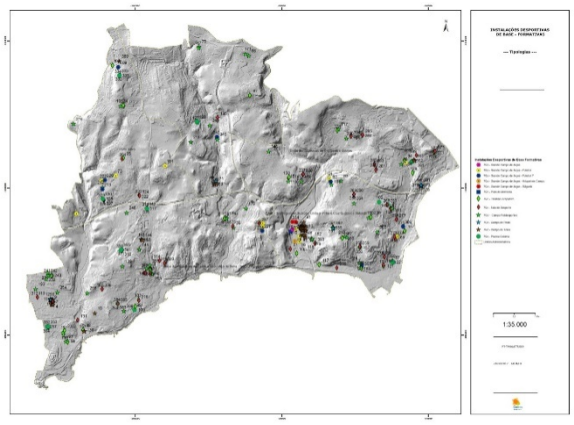

Fig. 1 Basic sports facilities-formatives.

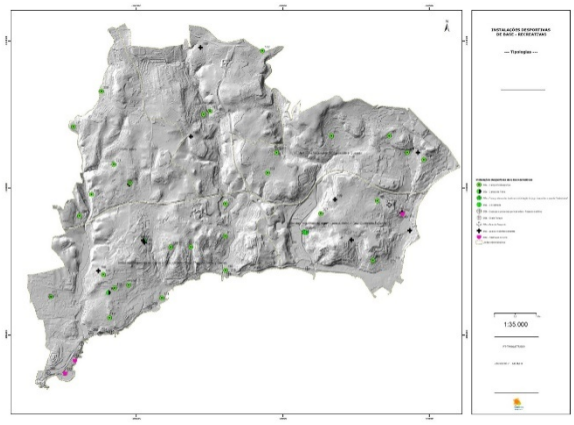

Fig. 2 Basic sports facilities-recreational.

and technological resources to support the public performance and diffusion of sporting events [6] (Table 4).

Their spatial distribution is shown in the map of Figs. 3 and 4. Given the special characteristics of this SF group, these are concentrated in the National Sports Center of Jamor.

The Oeiras Municipality has a Sports Map which dates from 2005, whose sports facilities classification is prior to the current legal regime of sports facilities for public use. Thus, in the scope of this project, the first task consisted, on the one hand, in updating the location of SFs, however outdated and in reclassifying them according to the current legal regime of sports facilities for public use. At this stage, the contribution of the Oeiras Municipality Sports

Table 3 Specialized or monodisciplinary sports facilities (S/MSF).

Typologies	Codification	Description
Specialized or monodisciplinary sports facilities	82a	Pavilions and sports halls designed and equipped for a specific modality
	82b	Rooms equipped exclusively for combat sports
	82c	Olympic swimming pools, diving pools and special tanks for underwater activities
	82d	Closed-loop cycling trails and regulatory tracing
	82e	Shooting installations with firearms
	82f	Archery facilities
	82g	Slopes and infrastructures for motor sports on land
	82h	Facilities for sporting activities
	82i	Rowing and canoeing and ground infrastructures to support water sports
	82j	Golf courses
	82l	Other sports facilities

Table 4 Special sports facilities for the sports show (SSFSS).

Typologies	Codification	Description
Special sports facilities for the sports show	92a	Stadiums
	92b	Sports multipurpose pavilions
	92c	Aquatic stadiums and Olympic pool complexes
	92d	Racetracks
	92e	Velodromes
	92f	Aerodromes, motodromes, kart tracks and cross-roads
	92g	Water sports stadium
	92h	Other enclosures

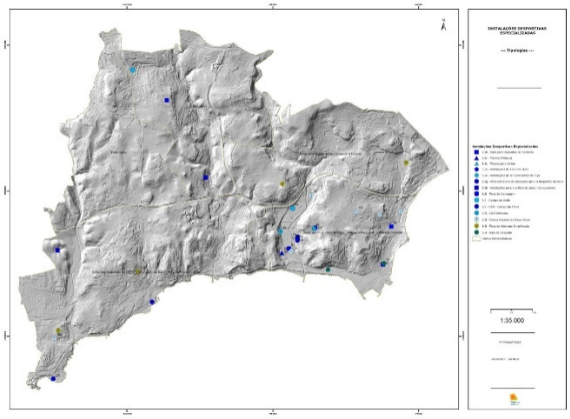

Fig. 3 Specialized or monodisciplinary sports facilities.

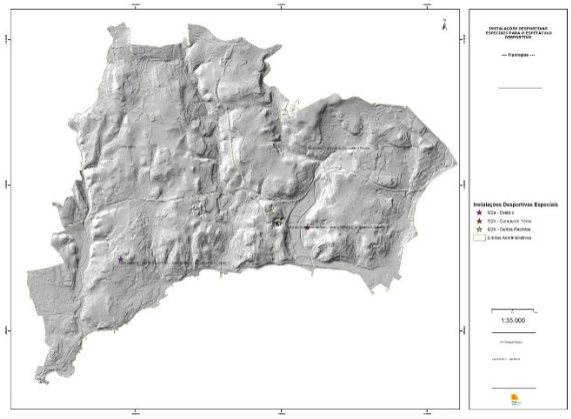

Fig. 4 Special sports facilities for the sports show.

Table 5 List of sports facilities by type.

Typology code	Description	Amount	
		#	%
62a	Enclosures, courtyards, minicamps and elementary spaces created for sport games, traditional games and physical exercises.	35	8.9
62b	Permanent spaces and courses organized and designed for the free evolution, races or fitness exercises, including the use of skates or recreational bicycles.	14	3.5
62c	Open rooms and enclosures, with practice area of free dimensions, for activities of maintenance, leisure, recreational games, table games and uncoded sports games.	17	4.3
62d	Indoor or outdoor pools, with free configuration and dimensions, for recreative, leisure and fitness.	3	0.8
72a	Large fields for football, rugby and field hockey.	24	6.1
72b	Athletics tracks, closed-loop, outdoor and with regulatory tracing.	1	0.3
72c	Sports halls and multipurpose sport halls.	129	32.7
72d	Small fields, multi-sports fields, tennis courts and skating rinks, outdoors or with simple coverage.	114	28.9
72e	Outdoor or indoor swimming for learning and multipurpose sports.	21	5.3
82a	Pavilions and sports halls designed and equipped for a specific modality.	0	0.0
82b	Rooms equipped exclusively for combat sports.	2	0.5
82c	Olympic swimming pools, diving pools and special tanks for underwater activities.	2	0.5
82d	Closed-loop cycling trails and regulatory tracing.	0	0.0
82e	Shooting installations with firearms.	2	0.5
82f	Archery facilities.	0	0.0
82g	Slopes and infrastructures for motor sports on land.	2	0.5
82h	Facilities for sporting activities.	3	0.8
82i	Rowing and canoeing and ground infrastructures to support water sports.	1	0.3
82j	Golf courses.	2	0.5
82l	Other sports facilities.	19	4.8
92a	Stadiums.	2	0.5
92b	Sports multipurpose pavilions.	0	0.0
92c	Aquatic stadiums and Olympic pool complexes.	0	0.0
92d	Racetracks.	0	0.0
92e	Velodromes.	0	0.0
92f	Aerodromes, motodromes, kart tracks and cross-roads.	0	0.0
92g	Water sports stadium.	0	0.0
92h	Other enclosures.	2	0.5
Total	-	395	100.0

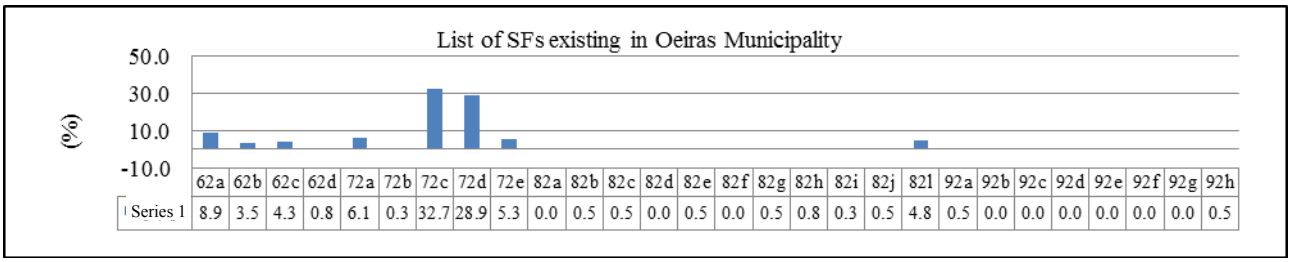

Fig. 5 List of sports facilities by type.

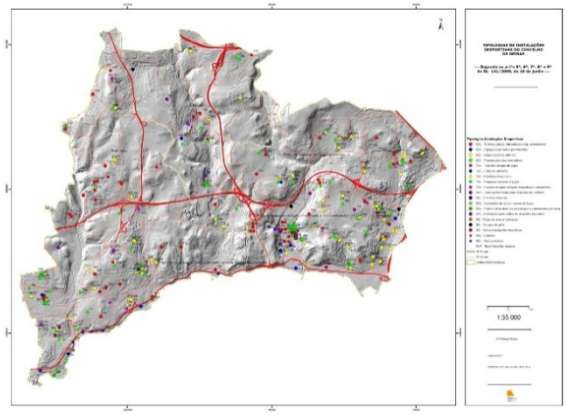

Fig. 6 Spatial distribution of all sports facilities.

Division and recognition work on the ground was predominant.

There are 395 sports facilities in the Oeiras Municipality, which are distributed according to the Fig. 5 and Fig. 6. "Sports pavilions and multipurpose sports halls" (72c) and "small indoor sports fields, multi-sports fields, tennis courts and skating rinks, indoor or outdoor" (72d) account for 62% of scheduled sports facilities in the county.

In the scope of Basic Sports Facilities-Recreational, the most representative are the enclosures, courtyards, minicamps and elementary spaces destinated to initiate the sports games, the traditional games and the physical exercises (62a), with 9% of the total SFs. This can be seen at Table 5 and Fig. 5.

The spatial distribution of all sports facilities is shown in Fig. 6.

2.2 Creation of a Global Friction Surface

The construction of a global friction surface on the public space, which translates into pedestrian mobility in the Oeiras Municipality, was the starting point for determining sports facilities service area.

The methodology of creation of this surface was based on the cost-distance model of the research work for the urban green space programming, for the Oeiras Municipality [4].

For this, a global friction surface resulting from the weighted integration of two friction surfaces was considered; one that reflects the speed of pedestrian movement in function of the friction created by the rugosity of the terrain and another one that expresses the speed of pedestrian movement according to the friction caused by the architectural public space characteristics, namely the typology, width, existence of architectural barriers, etc.

Fig. 7 and Table 6 contain the reference values of pedestrian movement according to the slope and the architectural characteristics of the public space.

Through classical mechanics formalizations it is possible to represent space e and time t, depending on each other.

From the global friction surface (Fig. 8) and from existing sports facilities an accumulated cost surface

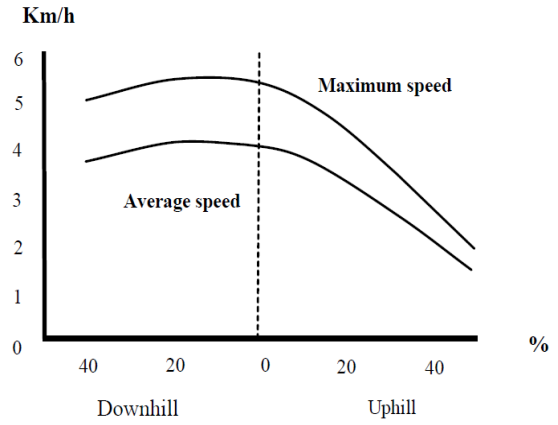

Fig. 7 Pedestrian travel speed depending on the slope [10].

Table 6 Pedestrian average speed (m/s and km/h) [1].

Modal walking width (m)/typologies of public spaces	Average walking speed (V) (m/s)	Average walking speed (V) (km/h)
0.00-0.90	0.00-0.75	0.00-2.70
0.90-1.20	0.75-0.98	2.70-3.50
1.20-1.80	0.98-1.22	3.50-4.40
> 1.80	1.22-1.81	4.40-6.50
Footpath	1.81-2.40	6.50-8.60
Zebra crossing	1.22	4.40
Road/parking/crossings	0.75	2.70
Car traffic separator and roundabout interior	0.00	0.00

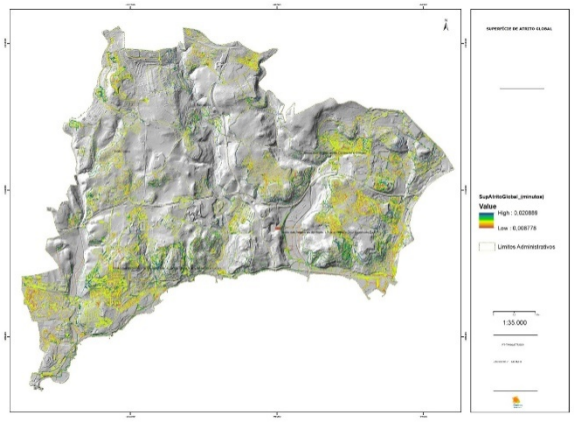

Fig. 8 Overall friction surface.

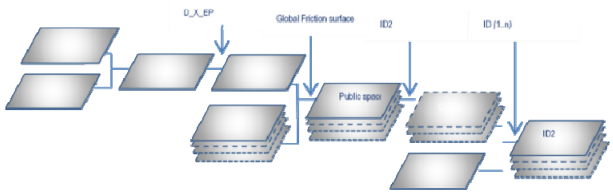

Fig. 9 Algorithm for determining service areas.

was generated which expresses the "cumulative cost" in minutes of crossing each pixel in meters. The conversion of distance-time and distance-space on a 2D surface is performed from the formalization of classical mechanics:

$$e = v \cdot t \quad (1)$$

being e the distance, v the speed and t the time.

2.3 Generating Services Areas

Based on the overlapping of the census geographic base (BGRI) of the National Statistical Institute (INE), with non-Euclidean surfaces of accumulated cost space and time and subsequent spatial reclassification, (AI, 1 ... n) we obtained the service areas (ID, 1 … n), whose spatial dimension obeyed the programming criteria of the BSF-Formative, listed in the following table, and published by DGOTDU [5].

It should be noted that the service areas generated had only as a pedestrian reference mode shift in detriment of the motorized mode.

The algorithm that served as the basis for the generation of the service areas of the SF can be seen in Fig. 9.

3. Space Coverage Analysis

The spatial coverage analysis aims to study the areas which meet the localization criteria of the DGOTDU (Table 1) by SF type and the deficit covered areas, from the spatial point of view and the statistical indicators provided by the census (Table 1) by SF type and the deficit covered areas, from the spatial point of view and the statistical indicators provided by the census base with block.

3.1 Service Areas of Basic-Formative Sports Facilities

According to the algorithm defined in Fig. 8 (generation algorithm of the service areas), several layouts were generated for each type of SF. Each graphic output corresponds to a map with the spatial location of the BSF-Formative and its area of influence, according to DGOTDU criteria and its irradiation by the road axes that constitute the public space. In each map, the shades of green represent the service areas that meet the benchmark criteria and the red color areas of poor spatial coverage (PSC).

(1) 72a—Large fields for football, rugby and field hockey (Fig. 10)

DGOTDU criteria:

- 2 to 3 km on foot or 15 to 20 minutes by public transport.
- Minimum base population: 2,500 inhabitants. The population of the Oeiras Municipality effectively served by this typology is 153,327 residents for 24 SFs, which represents a minimum base population of 6,388 inhabitants.

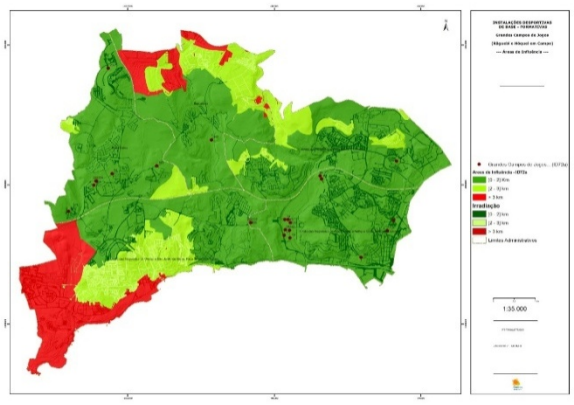

Fig. 10 Service areas of 72a.

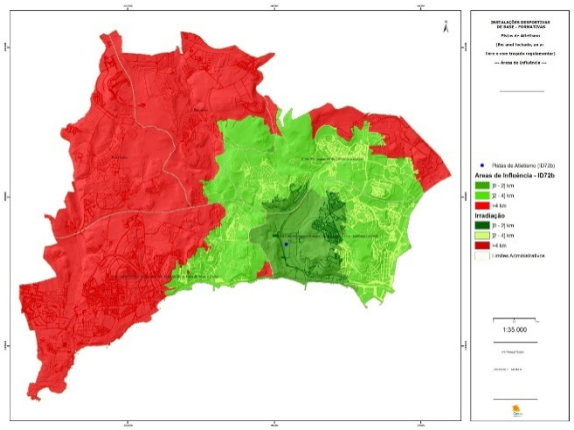

Fig. 11 Service areas of 72b.

(2) 72b—Indoor and outdoor track and field tracks with regulation tracing (Fig. 11)

DGOTDU criteria:

- 2 to 4 km on foot or 15 to 20 minutes by public transport.
- Minimum basic population: 7,500 inhabitants. The population of the Oeiras Municipality effectively served by this type of SF is 91,063 residents.

(3) 72c—Sports halls and multipurpose sports halls (Fig. 12)

DGOTDU criteria:

- 2 to 4 km on foot or 15 to 30 minutes by public transport.
- Minimum population of 3,000 inhabitants. The population of the Oeiras Municipality effectively served by this typology is 172,119 residents for 129 SFs, which represents a minimum base population of 1,334 inhabitants.

(4) 72d—Small fields, multi-sports courts, tennis courts and skating rinks, outdoors or with simple coverage (Fig. 13)

DGOTDU criteria:

- 0.5 to 1 km on foot or 5 minutes by public transport.
- Minimum basic population: 800 inhabitants. The population of the Oeiras Municipality effectively served by this typology is 155,827 residents for 114 SFs, which represents a minimum base population of 1,367 inhabitants.

(5) 72e—Outdoor or indoor swimming pools for learning, sports and multipurpose (Fig. 14)

DGOTDU criteria:

- 2 to 4 km on foot or 15 to 30 minutes by public transport.
- Minimum basic population: 5,000 inhabitants. The population of the municipality of Oeiras

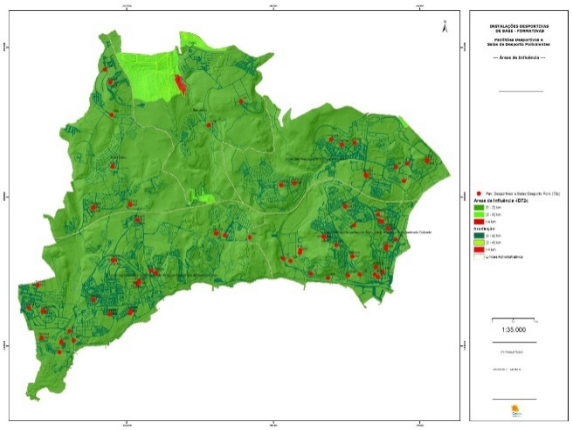

Fig. 12 Service areas of 72c.

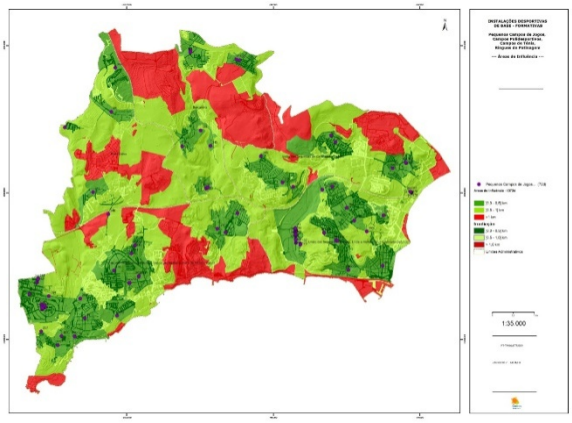

Fig. 13 Service areas of 72d.

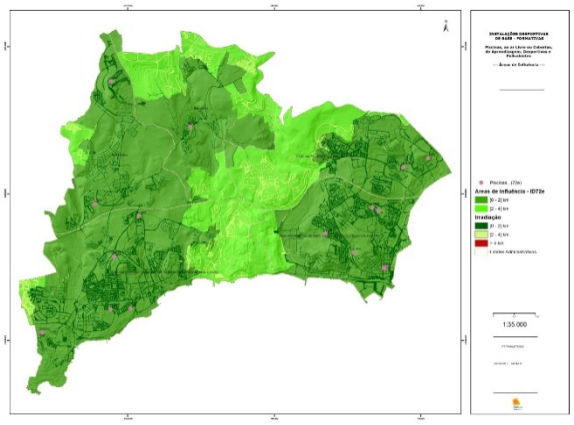

Fig. 14 Service areas of 72e.

effectively served by this typology is 172,120 residents for 21 SFs, which represents a minimum base population of 8,196 inhabitants.

In summary, the Oeiras Municipality presents an excellent space coverage in the following typologies:

- 72c—Sports halls and multipurpose sport halls;
- 72e—Outdoor or indoor swimming for learning and multipurpose sports.

As far as the demographic criterion is concerned, it can be seen that, in the whole municipality, each typology complies with the norms, except typology 72c, which paradoxically presents good spatial coverage.

The SFs for which there are deficient covered areas that will be the object of study under item "3. Programming of Sports Facilities based on Multicriteria Analysis", where the priority areas of intervention will be identified through a multicriteria decision support model.

3.2 Sociodemographic Profile of Service Areas

The delimitation of the service areas of the sports facilities is based on the statistical units of the INE (BGRI) with a spatial disaggregation to the urban headquarters for which a set of 131 statistical variables is available on the subjects: Individuals, Families, Family Groups, Lodgings and Buildings. Thus, service areas and areas of deficit coverage can be statistically characterized, with official information, and their sociodemographic profiles can be traced.

For the sociodemographic characterization of the sports facilities service areas we selected, in collaboration with the Sports Division, 22 statistical variables of the BGRI, with relevance to the study, according to Table 7.

From these indicators we can produce graphs that summarize the sociodemographic profile of the service areas and the areas of deficit coverage, in the themes:

- Residents;
- Population density;
- Aging index;
- Age groups;
- Resident education level;
- Situation of residents before employment;

Table 7 Sociodemographic variables for characterization of service areas.

Variables	Designation
RESIDENT	Total of residents
R0A4	Resident individuals aged 0 to 4 years
R5A9	Resident individuals aged 5 to 9 years
R10A13	Resident individuals aged 10 to 13 years
R14A19	Resident individuals aged 14 to 19 years
R20A64	Resident individuals aged 20-64 years
R_65	Resident individuals over 64 years of age
RENSC_1BAS	Individuals residing with the first cycle of basic education
RENSC_2BAS	Individuals residing with the second cycle of basic education
RENSC_3BAS	Individuals residing with the third cycle of basic education
RENSC_SEC	Resident individuals with complete secondary education
RENSC_PSEC	Individuals residing with post-secondary education
RENSC_SUP	Individuals residing with a full university course
REMPREG	Resident individuals employed
RPENS_REF	Resident pensioners or retred
R_S_ATECON	Individuals living without economic activity
CLAS1OU2	Classic families with 1 or 2 people
CLAS3OU4	Classic families with 3 or 4 people
CLASNPES65	Classic families with people aged 65 and over
ECLAS	Classic buildings
CLAS_RHAB	Classic accommodation of habitual residence
VAGOS	Vacant family accommodation

- Structure of classical families;
- Classical buildings and typologies of occupancy of dwellings.

3.3 Service Areas of Base Sports Facilities-Recreation

Although official criteria for the programming of recreational IDBs had not been established, we had the boldness to propose them, with the support of the Sports Division and in line with those for the Basic Sports Facilities-Recreational, given the high representativeness of this typology in the county of Oeiras.

Like the maps of the Basic Sports Facilities-Recreational, the following maps show the levels of coverage and the spatial irradiation of the Basic Sports Facilities-Recreational, allowing the visualization of areas with good and poor coverage.

We also used the same gradient color to represent the spatial variation of the service areas and the irradiation as in the Basic Sports Facilities-Recreational.

(1) 62a—Enclosures, courtyards, minicamps and elementary spaces created for sport games initiation, traditional games and physical exercises (Fig. 15).

Proposed criteria:

- 1 km on foot or 5 minutes by public transport.
- Minimum basic population: 800 inhabitants. The population of the Oeiras Municipality effectively served by this typology is 142,988 residents for 35 SFs, which represents a minimum base population of 4,085 inhabitants.

Comment:

The urban areas of the various places are well served in this SF typology.

(2) 62b—Permanent spaces and courses organized and designed for the free evolution, races or fitness exercises, including the use of skates or recreational bicycles (Fig. 16).

Proposed criteria:

- 1 km on foot or 5 minutes by public transport.
- Minimum basic population: 800 inhabitants. The population of the Oeiras Municipality effectively served by this typology is 43,931 residents for 14 SFs, which represents a minimum base population of 3,138 inhabitants.

Comment:

In this typology of SF, only the places at the south of the motorway and the waterfront are well served and equipped. In contrast, there is a large shade area, i.e., with poor spatial coverage.

(3) 62c—Open rooms and enclosures, with practice area of free dimensions, for activities of fitness, leisure, recreative games, table games and uncoded sports games (Fig. 17).

Proposed criteria:

- 4 km on foot or 30 minutes by public transport.
- Minimum population of 3,000 inhabitants. The population of the Oeiras Municipality really served

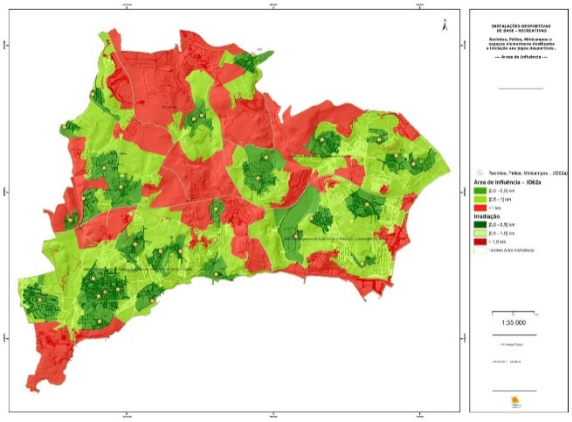

Fig. 15 Service areas of 62a.

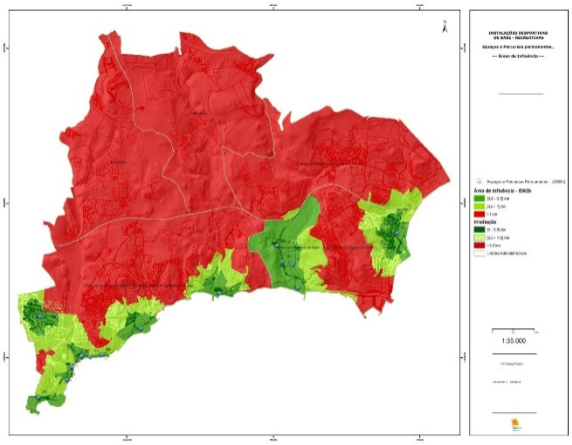

Fig. 16 Service areas of 62b.

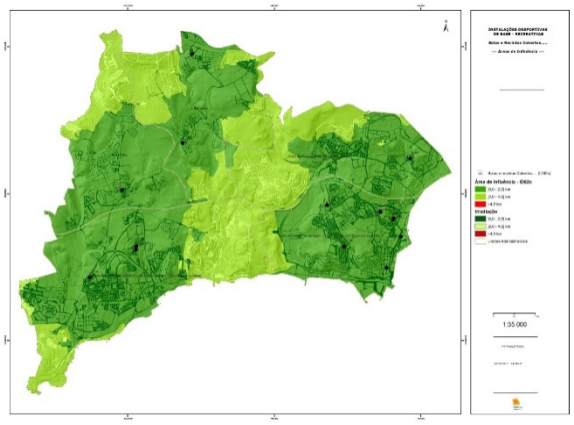

Fig. 17 Service areas of 62c.

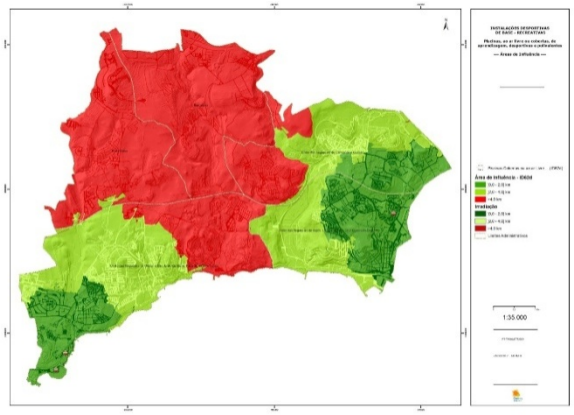

Fig. 18 Service areas of 62d.

by this typology of 172,120 residents for 17 SFs, which represents a minimum base population of 10,124 inhabitants.

Comment:

All the county of Oeiras is well served in this typology 62c.

(4) 62d—Indoor or outdoor pools, with free configuration and dimensions, for recreative, leisure and fitness (Fig. 18).

Proposed criteria:

- 4 km on foot or 20 minutes by public transport.
- Minimum basic population: 7,500 inhabitants.

The population of the Oeiras Municipality effectively served by this typology of 122,480 residents for 3 SFs, which represents a minimum base population of 40,827 inhabitants.

Comment:

The east and west county limits have full spatial coverage, with a large central shade area.

In summary, the Oeiras Municipality presents an excellent spatial coverage of the typology 62c—Open rooms and enclosures, with practice area of free dimensions, for activities of fitness, leisure, recreative games, table games and uncoded sports games. As for the demographic criteria, we can see that in the whole of the county each typology exceeds the minimum value of the population served.

4. Planning Sport Facilities

From the study made to the levels of spatial coverage of the SFs we can identify areas with deficit coverage. These areas are the study object for the establishment of priorities for intervention by the municipality, in terms of programming new sports equipment. For this we have adopted a weighted sum model based on the official scheduling criteria ("localization criteria") available (Table 1).

In this section we will describe this model to which we have designated Multicriteria Model to support the Programming of Sports Facilities.

4.1 Programming Criteria Definition

The designated Multicriteria Model to support the Programming of Sports Facilities is intended to identify spatially priority areas for sports facilities installation by establishing priority levels based on the "localization criteria" published by DGOTDU, 2002 (Table 1), namely the following:

(1) Locate yourself in close proximity to school equipment;

(2) Integrate as much as possible with other equipment;

(3) Complement with green spaces and play areas;

(4) Locate in a central position relative to the residential area to serve.

From the mentioned criteria we establish a "decision tree of criteria" that can lead us objectively to solve the problem (Fig. 19):

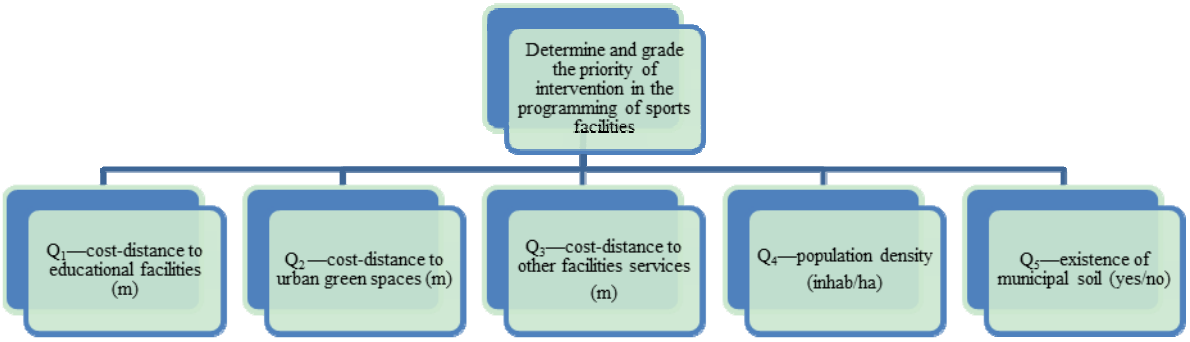

Fig. 19 Tree of multicriteria decision.

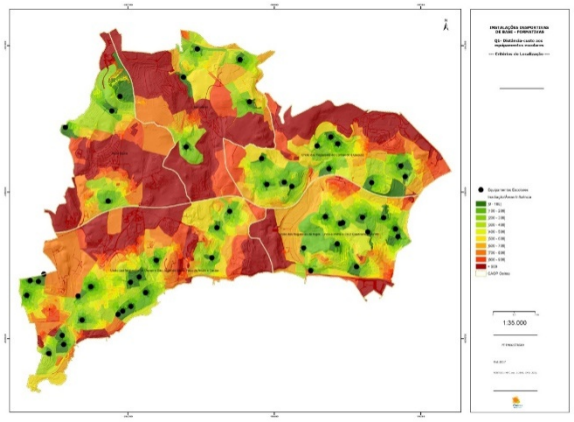

Fig. 20 Criterium Q_1—cost-distance to educational facilities.

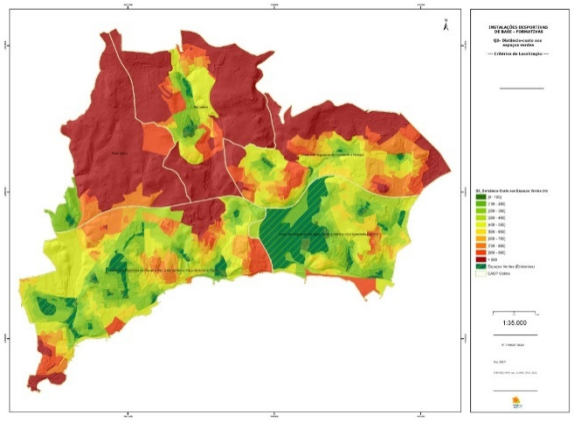

Fig. 21 Criterium Q_2—cost-distance to urban green spaces.

"How to determine and graduate intervention priorities in the programming of sports facilities"?

We first made sure that the criteria were not redundant, so as not to be as the results, and added a relevant criterion that is the "Availability of municipal soil", free of constraints.

The established criteria are as follows:

- Q_1—Cost-Distance to Educational Facilities;
- Q_2—Cost-Distance to Urban Green Spaces;
- Q_3—Cost-Distance to other Facilities Services;
- Q_4—Population Density;
- Q_5—Existence of Municipal Soil.

Let us go to the analysis of each of these criteria.

The criterion Q_1 represents the distances of pedestrian movement to school equipment, considering the friction caused by the slope of the land and by the typologies of the public space, for each 100 m of accumulated cost, being represented in Fig. 20.

The criterium Q_2 translates pedestrian distances into urban green spaces (Fig. 21), considering the friction resulting from the roughness of the terrain and the architectural features of the public space, for each 100 m of accumulated cost [4].

By analogy, criterium Q_3 represents the distances of pedestrian movement to other social facilities (Fig. 22), taking into account the friction resulting from the roughness of the terrain and the public space characteristics, per 100 m of accumulated cost.

Criterium Q_4 aims to translate the idea of "proximity to the residential area to be served" (Fig. 23), using the population density indicator, expressed in inab/ha. We used the reference values of urban planning standards [8], according to the following scale of increasing values:

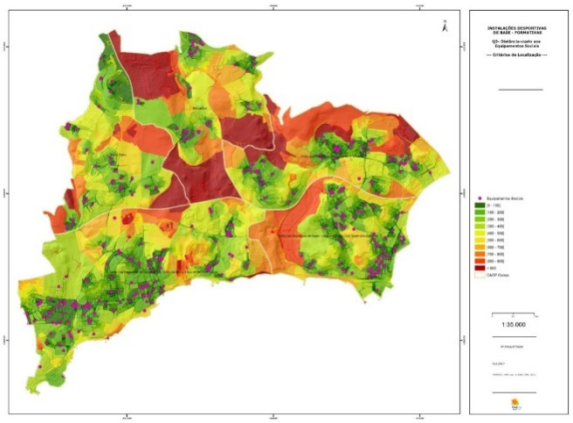

Fig. 22 Criterium Q_3—cost-distance to other facilities services.

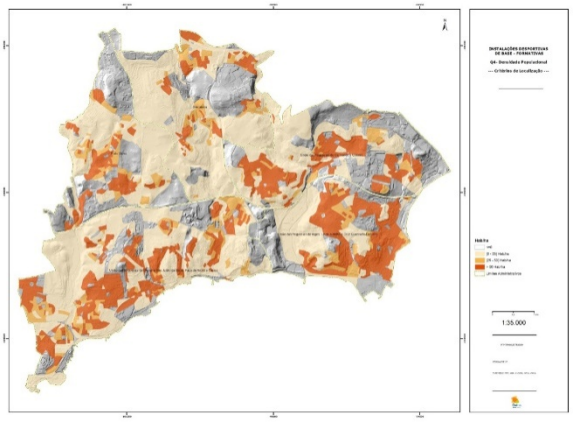

Fig. 23 Criterium Q_4—population density.

Q4 - Population density (inhab/ha)
<=0 - Null
]0 - 25] - Low
]25 - 50] - Medium
> 50 - High

We also considered the criterion "Q_5—Availability of Municipal Soil", where we identified the existence of compatible municipal soil with the installation of sports equipment with a formative basis (Fig. 24).

Table 8 establishes the minimum spatial dimension for the implementation of a training-based sports facility, depending on its typology.

Given the inexistence of municipal land, with the minimum area of implantation defined in the previous table, for the purposes of programming the Sports-Recreational Facilities Base, we only consider in pragmatic terms only the available municipal land and coming from urban land with a minimum surface 600 m^2 and free from urban restrictions.

In order to do so, the concession areas for the municipal private domain were analyzed, being compatible with the classification of "Urban Soil" (Master Plan) and free of constraints (RAN—National Agricultural Reserve, REN—National Ecological Reserve, SRUP—protected areas for built heritage) (Fig. 24).

Fig. 25 quantifies the areas available according to the type of to the land use conditioning.

The conditions for land use that fall on municipal land and that have not been included in this criterion refer to RAN, REN (Areas of Slope Instability, Transition Waters, Cliffs and Range of Protection to Transitional Waters) and Easements and Restrictions of Public Utility (Special Zone of Protection to Real Estate Classifieds). It was found that in 88.1% of the municipal soils there are restrictions on use and only 11.9% of soils were considered without conditioning factors.

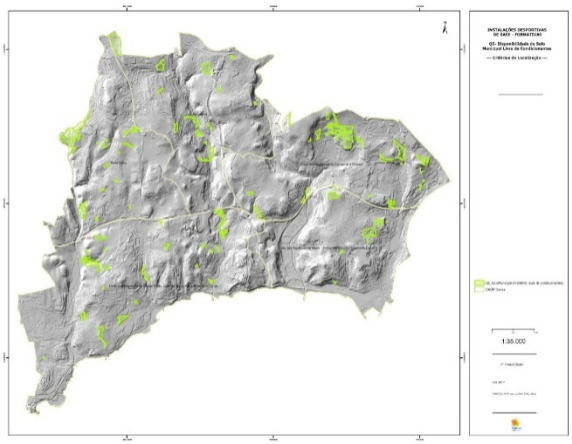

Fig. 24 Criterium Q_5—existence of municipal soil.

Table 8 Minimum areas of deployment by types of sports facility.

Typology code	Sport facilities type description	Minimum deployment area (m^2)
72a	Great playgrounds ...	7,500
72b	Athletics tracks	9,000
72c	Sports halls and multipurpose sport halls	720
72d	Small playgrounds, multi-sports courts, tennis courts ...	1,120
72e	Pools …	600

Source: Ref. [5].

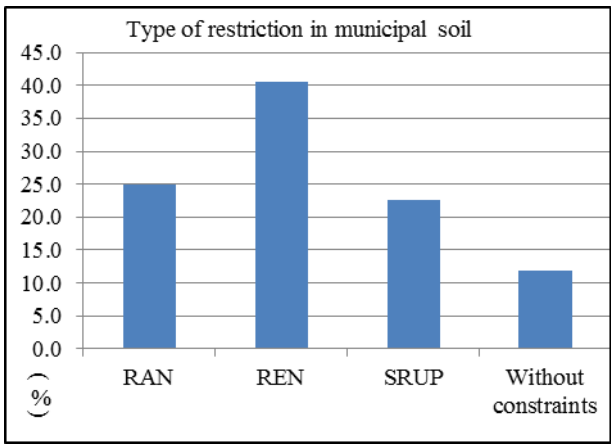

Fig. 25 Restrictions on municipal land use.

4.2 Weighting and Ordering of Criteria

The attribution of weights to the criteria considered in the multicriteria analysis proved to be more effective when considered according to each of the typologies of sports facilities, instead of the global attribution to all typologies. Thus, the weighting and respective ranking of the criteria were established according to the typology, as we can see on Tables 9 and 11.

The weight assignment was based on the Swing Weights method [9].

4.3 Service Areas Performances

The performance of the service areas of influence reflects the decision maker preferences for each of the alternatives under analysis according to the established criteria. The behaviour of the performances, according to the criteria, is given by the table and the function-value of the corresponding graph.

The criteria Q_1, Q_2 and Q_3 have the same scale of value and the factor pedestrian distance (cumulative) to public facilities and urban green spaces (Table 13 and Fig. 26).

The values of the cumulative cost-distance of 400 m were considered, this limit of indifference being the value beyond which the inclusion in the multicriteria model is justified.

The criterium Q_4 aims to value densely populated areas and penalize areas without residents, establishing the intermediate level for areas of average population density (Table 14 and Fig. 27).

Criterion Q_5 penalizes the absence of municipal land and maximizes its availability on a binary scale (Table 15 and Fig. 28).

Table 9 Weighting of criteria by type of sports facilities—basic sports facilities-formative.

		Weighting of Sports Facilities Typologies									
		72a		72b		72c		72d		72e	
Criteria	Description	Gross Value	Value %	Gross Value	Value %	Gross Value	Value %	Gross Value	Value %	Gross Value	Value %
Q1	Cost-Distance to Educational Facilities	18	23,7	18	23,1	16	22,9	16	23,5	18	23,7
Q2	Cost-Distance to Urban Green Spaces	13	17,1	15	19,2	9	12,9	9	13,2	12	15,8
Q3	Cost-Distance to other Facilities Services	15	19,7	13	16,7	15	21,4	13	19,1	16	21,1
Q4	Population Density	20	26,3	20	25,6	20	28,6	20	29,4	20	26,3
Q5	Existence of Municipal Soil	10	13,2	12	15,4	10	14,3	10	14,7	10	13,2
Total		76	100	78	100	70	100	68	100	76	100
Minimum deployment area (m2)		7500		9000		720		1120		600	

Table 10 Criteria ordering—basic sports facilities-formative.

Typologies codes	Typologies description	Criterium ordering
72a	Great playgrounds…	$Q_4 > Q_1 > Q_3 > Q_2 > Q_5$
72b	Athletics tracks	$Q_4 > Q_1 > Q_2 > Q_3 > Q_5$
72c	Sports halls and multipurpose sport halls	$Q_4 > Q_1 > Q_3 > Q_5 > Q_2$
72d	Small playgrounds, multi-sports courts, tennis courts...	$Q_4 > Q_1 > Q_3 > Q_5 > Q_2$
72e	Pools…	$Q_4 > Q_1 > Q_3 > Q_2 > Q_5$

Table 11 Weighting of criteria by type of sports facilities—basic sports facilities-recreational.

		Weighting of Sports Facilities Typologies							
		62a		62b		62c		62d	
Criteria	Description	Gross Value	Value %	Gross Value	Value %	Gross Value	Value %	Gross Value	Value %
Q1	Cost-Distance to Educational Facilities	18	24,7	15	18,5	15	20,5	16	20,5
Q2	Cost-Distance to Urban Green Spaces	10	13,7	18	22,2	10	13,7	9	11,5
Q3	Cost-Distance to other Facilities Services	15	20,5	16	19,8	18	24,7	18	23,1
Q4	Population Density	20	27,4	20	24,7	20	27,4	20	25,6
Q5	Existence of Municipal Soil	10	13,7	12	14,8	10	13,7	15	19,2
Total		73	100	81	100	73	100	78	100
Minimum deployment area (m2)		7500		9000		720		1120	

Table 12 Criteria ordering—basic sports facilities-recreational.

Typologies codes	Typologies description	Criterium ordering
62a	Enclosures, courtyards, minicamps and elementary spaces destined to the initiation to the sports games, the traditional games and the physical exercises.	$Q_4 > Q_1 > Q_3 > Q_2 \geq Q_5$
62b	Permanent spaces and courses organized and designed for the free evolution, races or maintenance exercises, including the use of skates or recreational bicycles.	$Q_4 > Q_2 > Q_3 > Q_1 > Q_5$
62c	Open rooms and enclosures, with practice area of free dimensions, for activities of maintenance, leisure, recreational games, table games and uncoded sports games.	$Q_4 > Q_3 > Q_1 > Q_2 \geq Q_5$
62d	Indoor or outdoor pools, of configuration and free dimensions, for recreational, leisure and maintenance uses.	$Q_4 > Q_3 > Q_1 > Q_5 > Q_2$

Table 13 Performances of the alternatives for the Q_1, Q_2 and Q_3 criteria.

Q_1, Q_2, Q_3 (m)	%
0-100	-
100-200	-
200-300	-
300-400	-
400-500	25
500-600	50
600-700	70
700-800	85
800-900	95
> 900	100

Table 14 Performances of the alternatives for the Q_4 criterium.

Q_4—population density (in hab/ha)	%
≤ 0 (null)	0
0-25 (low)	50
25-50 (medium)	80
> 50 (high)	100

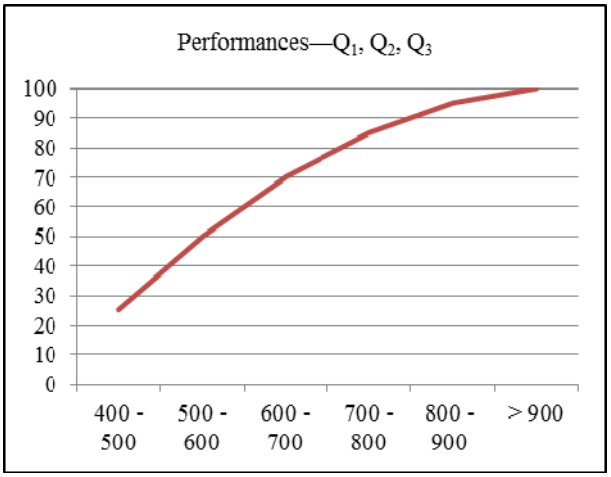

Fig. 26 Performances of the alternatives for the Q_1, Q_2 and Q_3 criteria.

- Q_1—Cost-Distance to Educational Facilities;
- Q_2—Cost-Distance to Urban Green Spaces;
- Q_3—Cost-Distance to other Facilities Services;
- Q_4—Population Density;
- Q_5—Existence of Municipal Soil.

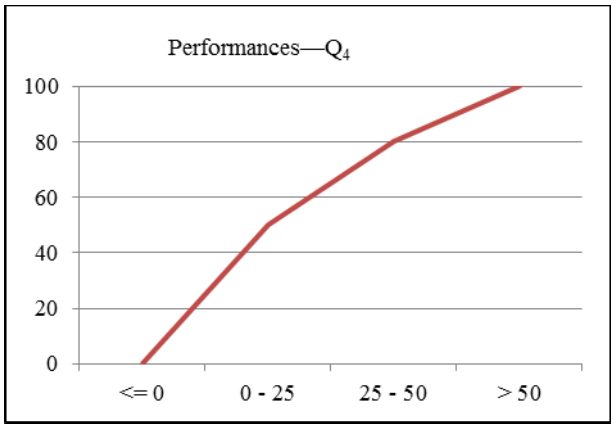

Fig. 27 Performances of the alternatives for the Q_4 criterium.

Table 15 Performances of the alternatives for the Q_5 criterium.

Q_5—existence of municipal soil (yes/no)	%
No	0
Yes	100

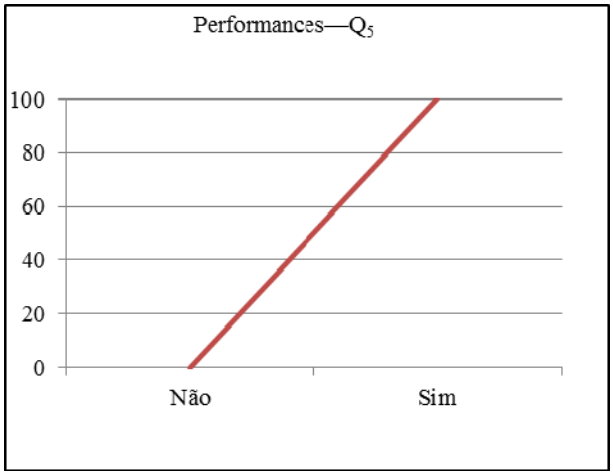

Fig. 28 Performances of the alternatives for the Q_5 criterium.

4.4 Determination of Intervention Priorities

The determination of the intervention priorities implies the application of the weighted sum model, by weighing the weight of each criterion by the respective performance, which is expressed by the intervention priority indicator (I_P):

$$I_p = \sum_{i=1}^{n} W_i \bullet Q_i \quad (2)$$

where, $0\% \leq I_p \leq 100\%$, W_i represents the weights and Q_i the performance, of each i criterion [7].

This indicator, expressed in quartiles, refers to each class 25% of the observations, with the step between 75% and 100% the highest intervention priority.

The order of the intervention priority is defined by the following cardinal scale, percentage, with the corresponding ordinal scale (Very Low, Low, Medium and High density):

Priority (%)
]0,00 - 25,00] - Very Low
]25,00 - 50,00] - Low
]50,00 - 75,00] - Medium
]75,00 - 100,00] - High

For the SFs that have deficient coverage areas, we applied the model from which the priority indicator (I_P) was derivate and the corresponding intervention priority maps were generated. The maps corresponding to Figs. 29-35 explain, for the BSF-Formative typologies (72a, 72b, 72c and 72d), for which "shadow areas" were identified, four classes of intervention priorities, on a percentage scale. The I_P values of more than 50% represent the most needed areas of sports equipment, with the class 75.00%-100.00% being the highest intervention priority in terms of sports facilities programming. This indicator provides relevant information to decision making, but should be interpreted in the context of the terrain and other socio-demographic variables.

4.4.1 Basic Sports Facilities-Formative

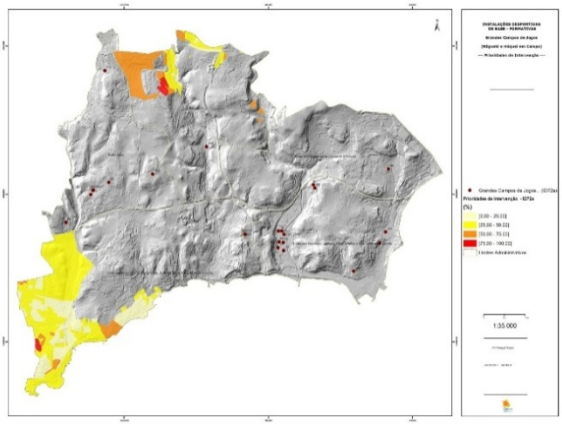

Fig. 29 Large playing fields (72a).

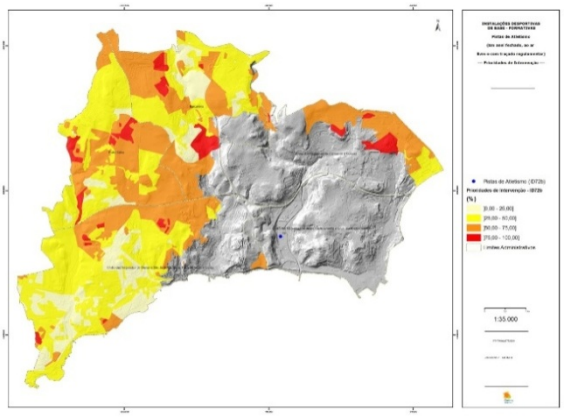

Fig. 30 Athletics tracks (72b).

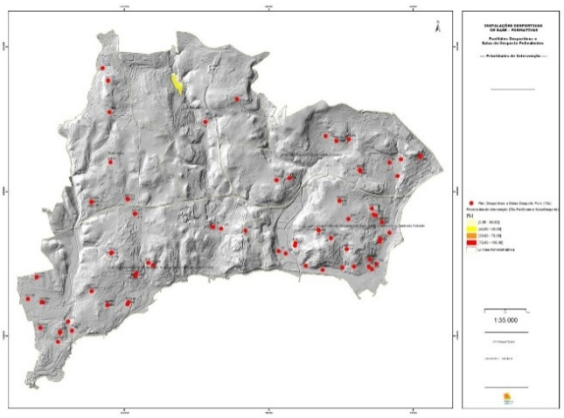

Fig. 31 Sports halls and multipurpose sport halls (72c).

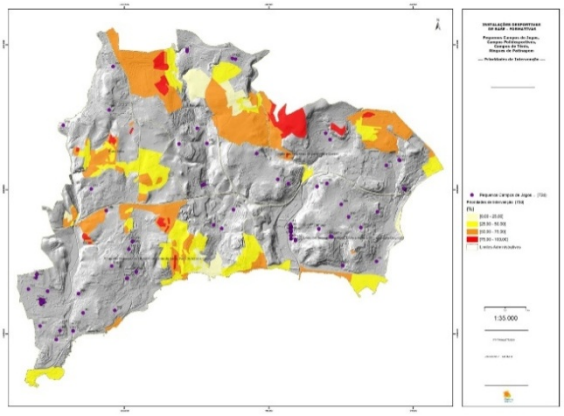

Fig. 32 Small playgrounds, multi-sports courts, tennis courts ... (72d).

4.4.2 Basic Sports Facilities-Recreational

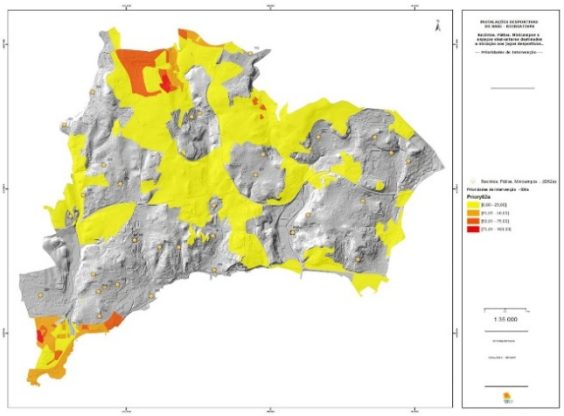

Fig. 33 Enclosures, courtyards, minicamps and elementary spaces intended for the initiation of games ... (62a).

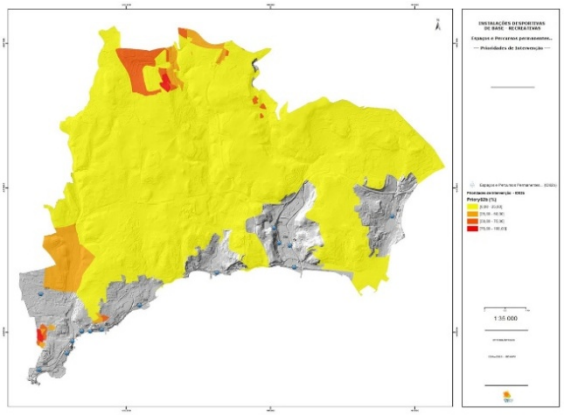

Fig. 34 Permanent spaces and paths organized and designed for free evolution ... (62b).

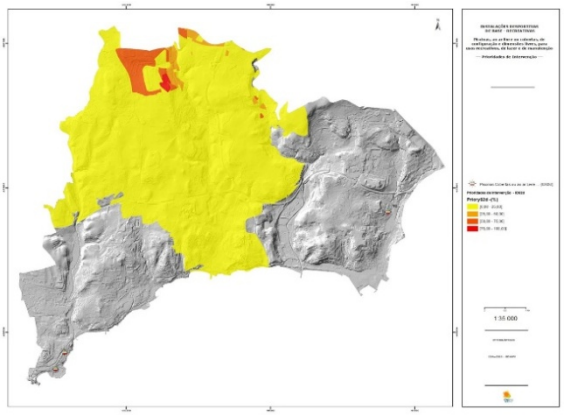

Fig. 35 Indoor or outdoor swimming pools ... (62d).

5. Conclusions

The model that expresses the pedestrian movement developed in this project was adequate to the reality of the Oeiras Municipality, translating the territorial mobility, taking into account the factors of friction such as the roughness of the terrain and the public space architectural characteristics, constituting an adaptation of the work developed for the programming of green spaces for the same municipality [4].

The weighted sum model used for the prioritization of areas with deficit spatial coverage adopted the ex-DGOTDU's sports equipment programming criteria such as: (i) to be located in the school equipment neighborhood; (ii) to integrate as closely as possible with other equipment; (iii) complementing with green spaces and leisure areas; and (iv) locating in central position in-relation to the residential area to be served.

The outputs generated allow the accuracy of analysis of the scale 1:2,000 and translate the areas of influence of the sports equipment in a pedestrian mobility view, in a network, by the public space and also the graduation of the priorities in the planning of the same equipment, through the indicator of established intervention priority.

The obtained results allow supporting the sports equipment planning and programming, in a more reasoned perspective and of a greater rationality of the offer in the field.

In the "shadow areas" there is the possibility of sports facilities planning and programming in an intermunicipal and economic of scale perspective.

The criteria established for the programming of BSF-Recreational are a proposal since only criteria for BSF-Recreational are available.

A new approach is proposed in equipment provision areas of the Oeiras Municipality in order to be free of constraints, and the minimum area necessary for the implantation of equipment should be guaranteed, in accordance with the programming rules of the sports facilities.

This work is innovative for the multicriteria approaches developed, in compliance with existing national standards, and the results should be interpreted with priority indicators to support the new sports facilities planning/programming.

The developed models here described have their spatial replication in other national and international municipalities, and can be adapted to other criteria.

Acknowledgement

I am grateful to the Oeiras City Council for making the road network and cartography of relief representation available. I thank the Sport Division of the Municipality of Oeiras for their collaboration in this project. This article was funded by FCT UID / AUR / 04494/2019.

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