Landscape Architecture

ARTICLE

Service-Reach and Cooling-Load Coupling for Civic Facility Siting in Semi-Arid BenGuerir, Morocco

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Abstract

Siting civic facilities in semi-arid settings should take into account both the need to locate facilities within a certain range from the people in terms of access to their services and the fact that some buildings are more sensitive to temperature than others. This analysis of a 29.5 ha plot located in the Green City of BenGuerir in Morocco is based on the data such as program areas, G+ floor configurations, the distance up to which people are willing to travel for certain types of facilities, population density, lighting loads, equipment loads, ventilation and air changes per hour, cooling and heating setpoint temperatures, wall and roof surface heat transfer coefficients, window solar heat gain coefficient, and annual cooling and heating intensities. As the result of calculations, mixed-use facilities demonstrate the highest internal gain intensity (65.28 $W\,m^{-2}$), followed by the gymnasium (55.05 $W\,m^{-2}$), the police center (49.10 $W\,m^{-2}$), the secondary school (45.52 $W\,m^{-2}$), and the primary school (43.73 $W\,m^{-2}$). At the same time, residential buildings and the polyvalent room show the lowest figures (18.98 $W\,m^{-2}$ and 19.15 $W\,m^{-2}$). With regard to access requirements, primary schools and mixed-use facilities have the most important priority due to their preferred service distance being 750 m, while masjids and polyvalent rooms are second in order (1200 m). The annual cooling intensity is 51.13 $kWh\,m^{-2}\,year^{-1}$, while the annual heating intensity is 25.18 $kWh\,m^{-2}\,year^{-1}$. Thus, the coefficient equals 2.03. The obtained results suggest that high internal gain activities are to be avoided along.

Keywords: semi-arid district planning; civic facility siting; service distance; internal gains; cooling demand; urban building energy modelling; BenGuerir.

1. Introduction

A parcel's zoning class does not tell the whole story about the accessibility of a service or the impact of its operations on thermal comfort and energy use. It reveals which people are likely to be within walking reach of a program, which journeys will have to traverse the exposed city, which programs are likely to experience a gain effect, and which parcel edges are amenable to development with low-gain construction. The latter issues are particularly salient in semi-arid zones due to intense solar exposure, dry outdoor conditions, insufficient shading, and cooling-dominated building operation, which turn a service's apparent accessibility into an ecological weakness.

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A program may be located conveniently but still be prone to solar gain, heat from paved surfaces, and cooling loads. A program with a lower internal heat release would be well-suited for an exposed or less central parcel if it did not harm the provision of services.

In BenGuerir, the program siting calculation is built around four key considerations. First, a check of the area and service-distance constraints verifies the feasibility of each program type. Second, the program's internal heat release intensity is determined based on lighting, equipment, and sensible occupancy loads. Third, access priority is assessed using preferred service distance criteria. Finally, when the program with high internal heat release coincides with a location of high thermal exposure, a penalty based on cooling intensity is imposed. The described approach allows one to keep the discussion grounded in the actual BenGuerir values and avoid reducing civic siting to solely centrality or energy-related considerations.

Studies in urban design and transport planning inform the discussion of accessibility. Hansen conceptualized accessibility as the capacity of locations to interact with opportunities [13]. Cervero and Kockelman subsequently confirmed that density, diversity, and the orientation towards pedestrians affect trip-making [3]. Geurs and van Wee defined accessibility as a land-use, transportation, temporal, and individual problem, which means that spatial reach cannot be considered in isolation [10]. Litman similarly emphasized the capacity of people to reach various activities and services, and it is quite clear that the notion is relevant for schools, places of worship, health-care facilities, and mixed-use zones [17]. In a parcel-scale problem with the allocation of services, service-distance limits cannot be treated as purely numerical parameters. They imply social frequency, age dependency, local reliance, and walking effort.

The urban design and legibility literature explains the relevance of reach as a property associated with the configuration of streets rather than parcel boundaries. Concepts of centrality proposed by Freeman help understand the roles of connector, near destination, and bridge in a network [9]. Studies of space syntax reveal that street layout and visibility affect movement and legibility [14]. Lynch's ideas on urban imageability and Marshall's analyses of street networks indicate that public programs should not be placed just within some radius; they should be visible, easily recognizable, and connected via walkable routes [18, 19]. For BenGuerir, all these arguments apply because the schools, masjids, and mixed-use facilities should be able to offer easily accessible services to daily users.

Research into urban climate and building energy use provides the second half of the problem. Oke's work on the effects of geometry and radiation on the performance of streets remains fundamental [20]. Studies by Givoni, Erell and others, as well as Ratti et al., emphasize the significance of compact design, shading, form of buildings, and openings in a hot and dry climate [7, 11, 21]. Findings in outdoor thermal comfort research suggest that street design and pedestrian exposure are responsible for the walkability of outdoor urban spaces based on thermal indices [16, 24]. Microclimate investigations also confirm that local morphology and topography affect the exchange of radiation and air flow and thus the thermal performance of streets and surrounding buildings [1]. These arguments show that reaching particular locations is insufficient in a semi-arid zone. There is a need to pay attention to thermal exposure as well.

Studies on urban building-energy models demonstrate that urban building stocks must be evaluated taking into consideration occupancy, lighting and equipment load, scheduling and ventilation strategies, and physical properties of the envelope as well as geometry [2, 4, 5, 8, 15, 22]. Full simulations are necessary when the information on geometry, scheduling, and weather files is available. In many cases, however, the process of district design requires making assumptions about program areas and service distances before developing a parcel simulation. As Sailor shows, estimating anthropogenic heat generation is particularly important in a hot region because internal loads from building occupants and equipment affect thermal comfort [23]. BenGuerir values prove sufficient to estimate internal gains and conduct an access-cooling conflict identification calculation.

In early district planning, there is a common tendency to follow a sequential path from urban design to energy use. First, one checks that the desired program is indeed included in the list of possible uses at an acceptable distance. Then, another check is performed with respect to energy use and microclimate. Such an approach is convenient in terms of procedure but weak in terms of technical efficiency. It means that accessibility considerations get to choose the most accessible sites while energy and microclimate analysis is left to cope with the consequences.

BenGuerir is a good example because the available values are sufficiently specific to describe the layout but not too complicated to develop three-dimensional modelling. Thus, there is a possibility to identify the major program decisions before conducting full hourly calculations.

Schools, worship buildings, health centres, and other civic facilities are not the same uses. A school should be situated close to residential zones to serve students' needs and allow for comfortable walking. Masjids require good visibility in the neighbourhood and high attendance rates during certain times of the day. Mixed-use structures can be small in area but produce significant equipment and lighting loads and appear repeatedly along commercial frontages. Gymnasiums can be large and visible with relatively heavy equipment loads; nevertheless, their service range might differ from that of primary schools. All these differences are important for determining the accessibility of a use, its positioning relative to climate, and placing low-gain programs to compensate for excessive energy consumption elsewhere in a parcel.

This section specifies the program types whose location requires good accessibility and visibility, the uses which need to be placed in thermally moderate locations, and low-gain programs that can help build the perimeter with exposed urban edges where annual cooling demand is about two times higher than annual heating demand.

2. BenGuerir district variables and climatic boundary conditions

The study case refers to a district of 29.5 ha located within the Green City of BenGuerir, Morocco. The district program schedule includes residential buildings, a primary school, a secondary school, a health centre, a police centre, a masjid, mixed-use facilities, a gymnasium, a polyvalent room, and a sports ground. The recorded variables include program area, number of floors (including garage level), service-distance criterion, density of occupants per square metre of occupied area, lighting power density, electrical equipment load, ventilation mode, infiltration rate, heating and cooling setpoints, envelope thickness, wall U-factor, window solar heat gain coefficient, window U-factor, and heating and cooling intensity [6]. These quantities can be used to compare the program types until georeferencing of a parcel occurs.

The regional and district setting of the study area is illustrated by Figure 1. The first map pinpoints the study location on the globe, and the second view depicts the scale and civic-residential nature of the 29.5 ha district. On the right-hand side, the panel indicates the annual heating and cooling intensities used to evaluate the cooling penalty.

The contextual data presented in Figure 1 provide the first basis for an assumption concerning the environment. The annual cooling intensity is 51.13 kWh m^{-2} $year^{-1}$, while the annual heating intensity is 25.18 kWh m^{-2} $year^{-1}$. It results in the ratio of 2.03. This number does not imply the irrelevance of heating. It shows that one should be more careful with the selection regarding solar exposure, internal gain, and fenestration control than heat collection for the winter period. This climatic peculiarity determines why one might need to consider a cooling-sensitive schedule for the same service distance.

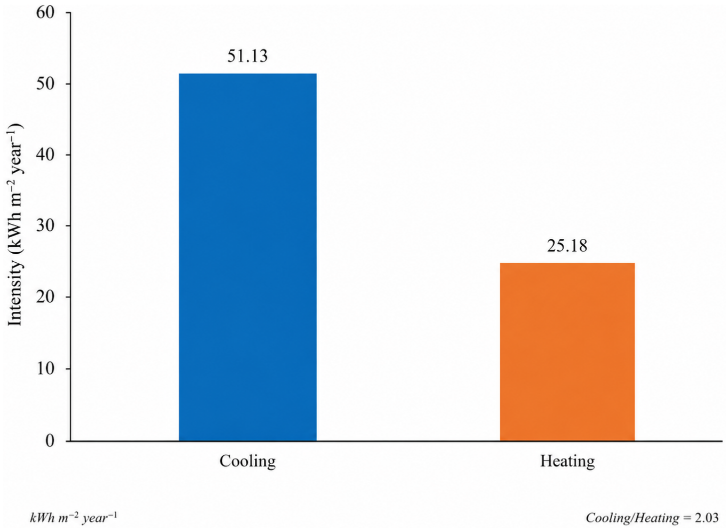
The building program parameters are shown in Table 1. The requirements for primary schools include 2000 ± 500 m^2, the G+1 type of construction, and the 750 m to 1200 m distance. For secondary schools, the requirements are 4000 ± 500 m^2, G+2, and 2300 m distance. For residential houses, the requirements are 150 m^2 to 400 m^2, G+4, and 2300 m to 3300 m. The requirements for the police centre and the health centre are 300 m^2 to 400 m^2 and 1000 ± 500 m^2 respectively, which are placed according to the 2300 m to 3300 m schedule. As for the masjid, it uses 200 m^2 to 500 m^2 and 1200 m service distance. Mixed-use facilities can use 0 m^2 to 150 m^2 of area and 750 m to 3300 m. The requirements for the gymnasium are 700 to 800

The program inventory is visualized in Figure 2. The three panels retain the recorded area, floor, and reach values but separate the functions by planning role so that educational, civic-residential, and community-sport demands can be compared without forcing them into a single visual category.

The visual grouping in Figure 2 clarifies why the calculation cannot be reduced to building size. A small mixed-use unit may carry strong daily-access relevance because of its 750 m lower service bound, while a larger gymnasium may tolerate a broader district catchment. Similarly, a residential block may be spatially repetitive and relatively flexible, whereas a primary school requires careful relation to residential demand and pedestrian safety. These differences guide how the subsequent gain and access indices should be interpreted.

(a) Regional location.

(b) District parcel.



(c) Annual intensity.

Figure 1. BenGuerir case context.

Table 1. Program constraints.

Building program	Area criterion (m^2)	Floor configuration	Service-distance criterion
Primary school	2000 ± 500	G+1	750 m to 1200 m
Secondary school	4000 ± 500	G+2	2300 m
Residential buildings	150–400	G+4	2300 m to 3300 m
Police centre	300–400	G+1	2300 m to 3300 m
Health centre	1000 ± 500	G+1	2300 m to 3300 m
Masjid	200–500	G+3	1200 m
Mixed-use facilities	0–150	G+5	750 m to 3300 m
Gymnasium	700–800	G+1	2250 m
Polyvalent room	1000–2000	G+3	1200 m
Sports ground	> 1100	G	2250 m

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(a) Education. **(b)** Civic and mixed use. **(c)** Community and sport.

Figure 2. Program constraint panels.

The operational assumptions used to calculate internal gain intensity are reported in Table 2. The values show that the main cooling-relevant differences are not governed by people density alone. The secondary school has the highest people density at 0.311 person m^{-2}, but mixed-use facilities have the highest equipment load at 43.8 W m^{-2}. The gymnasium also carries a high equipment value of 42.0 W m^{-2}, while the police centre reaches 34.5 W m^{-2}. Residential buildings and polyvalent rooms have much smaller equipment contributions, even though their infiltration values are higher than those of several civic functions.

Table 2. Operational inputs.

Building program	People density (people/m^2)	Lighting (W m^{-2})	Electric equipment (W m^{-2})	Ventilation	Infiltration ($m^3\,s^{-1}\,m^{-2}$)
Residential buildings	0.025	11.1	6.0	0.3 ACH	0.000569
Primary school	0.215	11.1	16.5	0.003 $m^3\,s^{-1}$ $person^{-1}$	0.000227
Secondary school	0.311	10.0	12.2	0.0023 $m^3\,s^{-1}$ $person^{-1}$	0.000227
Health centre	0.029	10.0	16.5	0.18 ACH	0.000227
Police centre	0.064	9.8	34.5	0.0018 $m^3\,s^{-1}$ $person^{-1}$	0.000212
Gymnasium	0.026	11.1	42.0	0.31 ACH	0.000569
Mixed-use facilities	0.125	12.1	43.8	0.06 ACH	0.000432
Masjid	0.196	10.1	2.3	0.00 ACH	0.000227
Polyvalent room	0.026	11.1	6.1	0.31 ACH	0.000569

The operational input table separates two types of cooling pressure. Schools and the masjid are influenced strongly by occupancy because people density is high relative to equipment. Mixed-use facilities, gymnasium, and police centre are influenced more strongly by equipment. This distinction is important because occupancy-heavy buildings require attention to schedules, ventilation, and classroom or hall comfort, whereas equipment-heavy buildings require attention to internal heat release, plug-load management, and cooling system sizing.

The envelope and setpoint assumptions are summarized in Table 3. Opaque components have U-values of 0.428 W m^{-2} K^{-1} for walls, 0.410 W m^{-2} K^{-1} for the roof, and 0.950 W m^{-2} K^{-1} for the floor. The window U-value is 2.551 W m^{-2} K^{-1}, and the solar heat gain coefficient is 0.25. The cooling setpoint is 26 °C, and the heating setpoint is 20 °C.

The envelope inputs show why exposed building placement matters even before detailed facade design. The window U-value is approximately six times the wall U-value and more than six times the roof U-value. High-gain programs placed on exposed frontages therefore require particular caution because internal heat release and fenestration sensitivity can reinforce one another under cooling-dominant operation.

The physical envelope reading in Figure 3 links program allocation to the thermal properties of the wall, roof, floor, and window assembly, rather than treating a building as a neutral point on a map.

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Table 3. Envelope inputs.

Parameter	Value
Cooling setpoint	26 °C
Heating setpoint	20 °C
Wall thickness	10 cm
Roof thickness	55 cm
Floor thickness	30 cm
Wall U-value	$0.428\,\mathrm{W\,m^{-2}\,K^{-1}}$
Roof U-value	$0.410\,\mathrm{W\,m^{-2}\,K^{-1}}$
Floor U-value	$0.950\,\mathrm{W\,m^{-2}\,K^{-1}}$
Window solar heat gain coefficient	0.25
Window U-value	$2.551\,\mathrm{W\,m^{-2}\,K^{-1}}$

Figure 3. Envelope parameters.

The contrast in Figure 3 supports a practical siting rule. When a high-gain program such as mixed-use, gymnasium, or police centre must occupy a visible frontage, the frontage should be shaded, oriented carefully, and given restrained fenestration rather than treated as a purely civic display surface. The same envelope values are less critical for low-gain residential or polyvalent functions, although they still affect annual energy demand.

3. Cooling-weighted allocation calculation

The applied calculation represents each program as a vector of area, floor, reach, operational, and thermal attributes:

$$\mathbf{x}_t = \left(A_{t,\min}, A_{t,\max}, F_t, R_{t,p}, R_{t,h}, P_t, L_t, E_t, V_t, I_t\right). \tag{1}$$

Here $A_{t,\min}$ and $A_{t,\max}$ are the admissible program-area bounds, F_t is floor configuration, $R_{t,p}$ is preferred service reach, $R_{t,h}$ is hard service reach, P_t is people density, L_t is lighting load, E_t is electric-equipment load, V_t is ventilation, and I_t is infiltration. A service-distance interval is read as a preferred-to-hard range; a single distance is read as both preferred and hard. This distinction allows the calculation to recognize that a facility may satisfy a maximum reach while still losing local access quality.

A candidate location j is physically feasible for program t when parcel size and hard reach are satisfied:

$$A_{t,\min} \le A_j \le A_{t,\max}, \qquad d_{ij} \le R_{t,h}. \tag{2}$$

The feasibility condition is intentionally strict. It prevents an attractive central site from being selected if the parcel cannot accept the program area or if the hard reach is violated. The sports ground remains in the program schedule because it is important to the district, but it is excluded from the indoor internal-gain calculation because no indoor lighting, equipment, occupancy, ventilation, or infiltration values are provided for it.

Program internal gain intensity is calculated as

$$G_t = L_t + E_t + q_p P_t, \tag{3}$$

where G_t is expressed in $\mathrm{W\,m^{-2}}$ and $q_p = 75\,\mathrm{W\,person^{-1}}$ converts people density into a sensible occupancy term. The value is used for relative ordering among the recorded programs, not as a substitute for dynamic energy simulation. The equation makes the contribution of people, lighting, and equipment visible in a form that can be applied before hourly schedules are available.

The normalized gain intensity is

$$\widehat{G}_t = \frac{G_t - \min(G)}{\max(G) - \min(G)}. \tag{4}$$

This transformation places all indoor programs on a common scale from the lowest calculated internal gain to the highest. A value close to 1 indicates a program that should be protected from unnecessary exposure, while a value close to 0 indicates a program that can more easily occupy thermally less privileged positions.

Access priority is calculated from preferred service distance:

$$\widehat{R}_t = 1 - \frac{R_{t,p} - R_{\min}}{R_{\max} - R_{\min}}. \tag{5}$$

The form of the equation assigns higher priority to shorter preferred distances. In the BenGuerir schedule, the 750 m tier receives the strongest local-access value, the 1200 m tier receives a strong neighbourhood value, and the 2250 m to 2300 m group receives lower local urgency because those functions can serve a wider catchment.

The cooling dominance coefficient is calculated as

$$\lambda_c = \frac{C_y}{H_y} = \frac{51.13}{25.18} = 2.03, \tag{6}$$

where C_y and H_y are annual cooling and heating intensities. This coefficient uses the BenGuerir annual energy balance to strengthen the penalty for placing high internal gains in exposed locations.

The composite suitability score for assigning program t to candidate location j is

$$\Phi_{tj} = \alpha\widehat{B}_j + \beta\widehat{C}_j + \gamma\widehat{S}_j + \delta\widehat{R}_t - \eta\left(\lambda_c\widehat{G}_t\widehat{H}_j\right). \tag{7}$$

Here $\widehat{B}_j$ is normalized betweenness, $\widehat{C}_j$ is normalized closeness, $\widehat{S}_j$ is legibility or visibility value, $\widehat{R}_t$ is access priority, $\widehat{G}_t$ is normalized program gain intensity, and $\widehat{H}_j$ is local thermal exposure. The weights determine how strongly movement, reach, legibility, access, and cooling moderation influence the final placement. The negative term is the critical semi-arid component: it penalizes a location only when a high-gain program and a high-exposure site coincide.

The score components in Figure 4 separate access, legibility, gain intensity, and local exposure so that each contribution can be inspected before a siting decision is accepted.

The score plate in Figure 4 explains why two programs can receive different recommendations at the same exposed parcel. A mixed-use facility can be attractive because of reach and legibility but still lose suitability when its normalized internal gain is high. A residential block may have weaker civic priority but a much lower internal-gain penalty, making it a better candidate for edge completion or buffering if access criteria are respected.

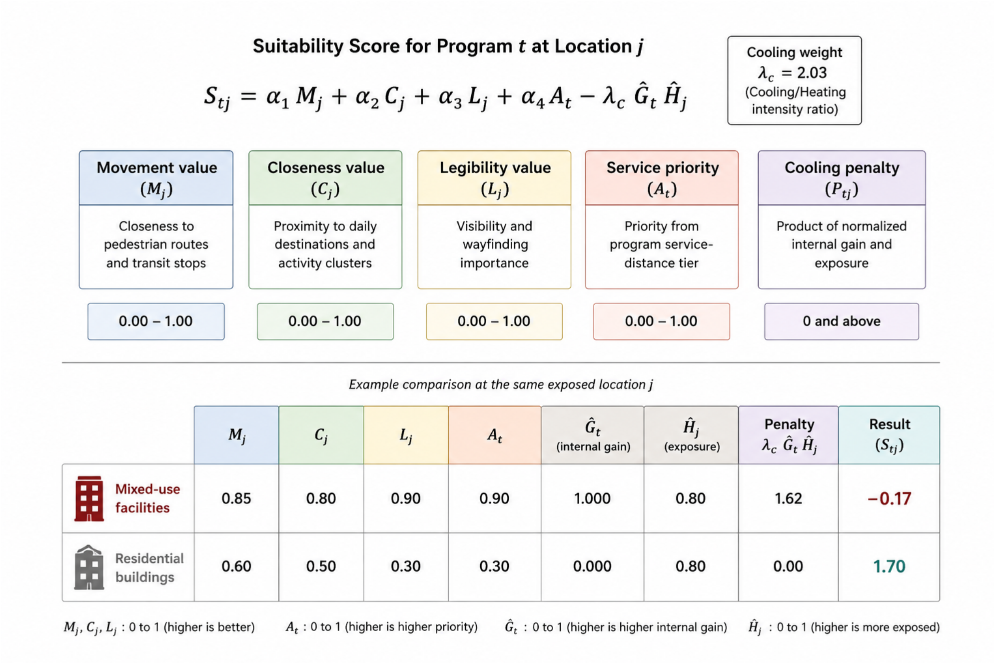

Figure 4. Cooling-weighted score.

For a fixed set of candidate locations, the assignment can be expressed as

$$\max_{y_{tj}} \quad \sum_t \sum_j \Phi_{tj} y_{tj}, \tag{8}$$

$$\text{subject to} \quad \sum_j y_{tj} = n_t, \quad \forall t, \tag{9}$$

$$\sum_t y_{tj} \le 1, \quad \forall j, \tag{10}$$

$$y_{tj} = 0 \quad \text{when Eq. (2) is violated}, \tag{11}$$

$$y_{tj} \in \{0, 1\}. \tag{12}$$

The decision variable y_{tj} equals 1 when a program is assigned to a candidate location, and n_t is the required number of facilities of that type. These constraints preserve the difference between permission and preference. Area and hard reach decide whether a placement is possible; the suitability score decides whether the placement is defensible under access and cooling considerations.

4. Results

The internal-gain ranking is dominated by equipment-heavy and occupancy-heavy programs. Mixed-use facilities reach 65.28 W m^{-2}, the largest value in the schedule, because lighting, equipment, and occupancy all contribute substantially. The gymnasium reaches 55.05 W m^{-2}, mainly because equipment is 42.0 W m^{-2}. The police centre reaches 49.10 W m^{-2}, again because equipment is high. Secondary and primary schools reach 45.52 W m^{-2} and 43.73 W m^{-2}, with occupancy playing a stronger role than in the gymnasium or police centre. The health centre and masjid occupy the moderate band. Residential buildings and the polyvalent room are the lowest-intensity indoor functions.

The internal-gain composition is shown in Figure 5. Lighting, equipment, and occupancy components follow Eq. (3) exactly.

The ranking in Figure 5 changes how the program schedule should be read. Mixed-use facilities are not thermally neutral simply because each unit is small. Their equipment and lighting loads make them the strongest cooling-sensitive indoor program. The gymnasium and police centre are also high-intensity despite broader catchments.

Schools occupy a different high-intensity category because their gains are strongly connected to occupancy and daily use. The low values for residential buildings and polyvalent rooms explain why these functions can support exposed edges more safely than mixed-use or gymnasium functions.

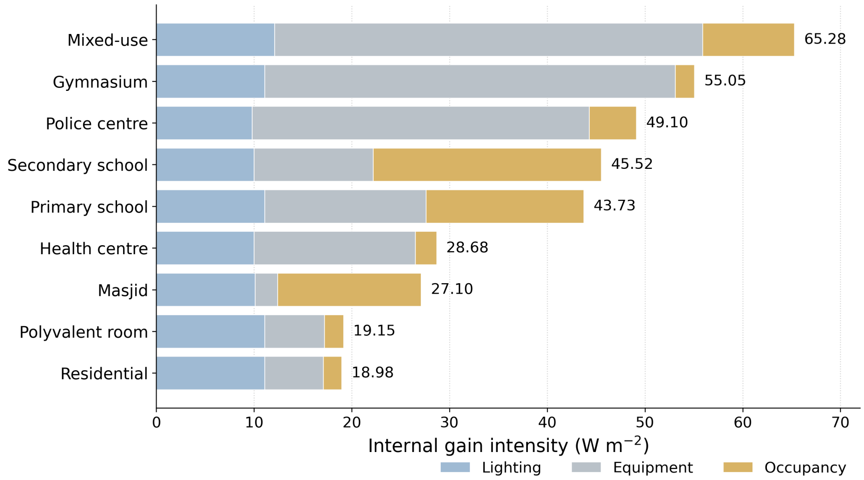

Figure 5. Internal gain intensity.

The calculated gain and access priority values are reported in Table 4. Mixed-use facilities have both the highest normalized gain and the highest access priority. Primary school has high access priority and a mid-high gain value. Masjid and polyvalent room share a strong access value, but their internal gains differ sharply. Gymnasium, police centre, secondary school, health centre, and residential buildings have low access-priority values because their preferred distances are wider.

Table 4. Gain and access indices.

Program	G_t (W m^{-2})	$\widehat{G}_t$	$\widehat{R}_t$
Mixed-use facilities	65.28	1.000	1.000
Gymnasium	55.05	0.779	0.032
Police centre	49.10	0.651	0.000
Secondary school	45.52	0.573	0.000
Primary school	43.73	0.535	1.000
Health centre	28.68	0.210	0.000
Masjid	27.10	0.175	0.710
Polyvalent room	19.15	0.004	0.710
Residential buildings	18.98	0.000	0.000

The numerical contrast in Table 4 is the central result of the paper. Access priority and cooling intensity do not move together. A primary school and a mixed-use unit both demand strong local reach, yet the mixed-use function is far more internally intensive. A masjid and a polyvalent room both belong to the 1200 m neighbourhood tier, yet the polyvalent room carries almost no normalized gain while the masjid has moderate occupancy-related heat. A gymnasium has very high gain but weak local-access urgency, which means it should be accessible but need not occupy the most exposed central frontage.

The relationship between preferred service distance and calculated internal gain is shown in Figure 6. The plot uses the same G_t values and preferred service distances as Table 4, allowing the access-thermal mismatch to be read directly.

From the point distribution on the chart Figure 6, three distinct siting scenarios emerge. The mixed-use facilities stand out as being most challenging due to their combination of very short reach with high internal gain. The primary school has very short reach and also has high internal gain, but it is subjected to less thermal pressure due to lower gain-to-pressure relation while having more social priority. The gymnasium, police centre, and secondary schools have high internal gain and large reach, thus, making them suitable for thermally more moderate locations such as the inner part of the parcel.

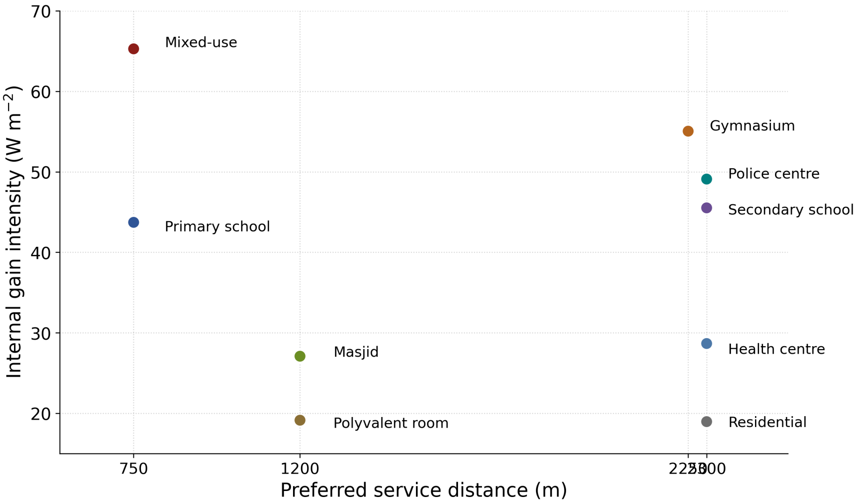

Figure 6. Service reach and gain.

It becomes even clearer by looking at the calculated cooling coefficient. An exposed site that has $\widehat{H}_j = 0.80$ produces a coefficient of $2.03 \times 1.000 \times 0.80 = 1.62$ for mixed-use facilities, but the same location produces almost no internal-gain penalty for residential buildings since the normalized internal gain is 0.000. The numbers highlight the difference between the cooling needs of the programs. Under conditions when accessibility and legibility are equal, the program that requires more thermal mitigation or an exposed siting is the one with greater internal gain.

Secondly, it needs to be noted that the annual cooling coefficient should be interpreted through the lens of accessibility and exposure and not as a climatic factor per se. A number of 2.03 is the ratio unique to BenGuerir based on recorded annual intensities. Other districts with similar rules but with the balanced heating and cooling needs will not necessarily generate the same need for siting priorities. The current situation highlights the importance of locating more intensive building types in areas where shading, orientation, and façade moderation will help to achieve cooling. Thus, the calculation distinguishes accessibility from exposure rather than assigning one climate variable to the whole set of public buildings.

Thirdly, the results also inform the social importance of each program based on their internal gain. Programs with low internal gains cannot be seen as less socially important buildings. Residential buildings have the lowest indoor gain of all analyzed, but at the same time, housing is essential for the functioning of the whole service area. The results highlight that the district could place residential buildings adjacent to other civic anchors without increasing the burden of additional internal gain, thus allowing using houses as transition spaces, buffers around open areas or exposed roads, and continuity elements of the urban layout while putting more intensive buildings into safer places. The polyvalent room shares the same characteristic in regard to community buildings: it retains its function but without imposing a load like gymnasium.

Fourthly, one should note the need to analyze the internal operations based on the gain scores since even with identical sums, two programs may need quite different strategies for thermal moderation. While the secondary school and primary school are intensive buildings with heat closely tied to occupancy, comfort within such programs requires managing crowdedness, ventilation, scheduling of classes and shaded approach. On the contrary, the gymnasium and the police centre receive more of their gain from the equipment, pointing to the need to manage this load through zoning and cooling equipment operation. The masjid has moderate totals but high people density compared to equipment loads, thus requiring managing of peak occupancy periods.

The siting interpretation in Figure 7 distinguishes high-access civic routes, thermally moderated interior positions,

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and exposed edge-buffer positions while retaining the same calculation.

Figure 7. Cooling-dominant siting bands.

The spatial interpretation in Figure 7 translates the numerical hierarchy into planning action. Primary schools, masjids, and selected mixed-use units should remain on accessible and legible routes, but mixed-use units should be distributed rather than concentrated. Gymnasium, police centre, secondary school, and health centre can occupy moderated interior positions because their broader reach allows more thermal discretion. Residential buildings and the polyvalent room can help complete edge conditions because their calculated gains are low.

The program-specific recommendations are summarized in Figure 8. The cards keep the gain values visible and pair each function with a siting condition derived from the same access and cooling calculations.

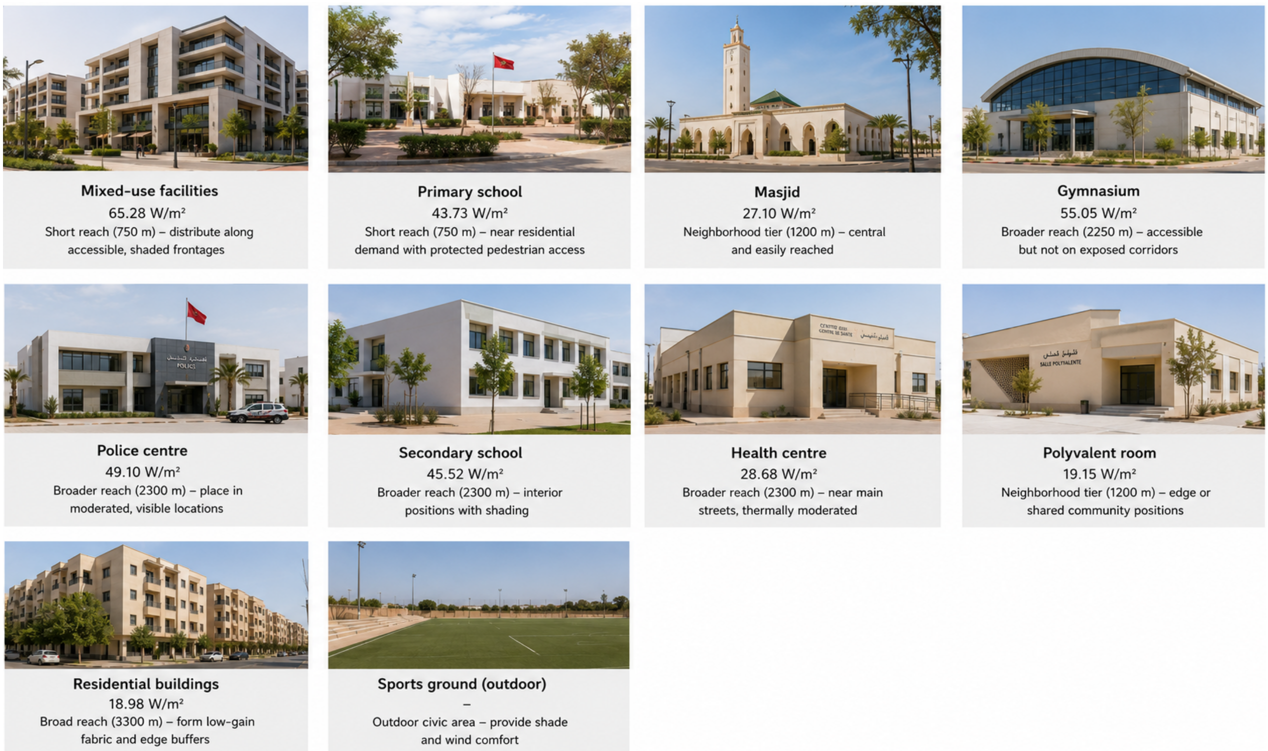

Figure 8. Program siting guidance.

The recommendation panel in Figure 8 translates the numerical hierarchy into siting recommendations. Mixed-use buildings should be located on accessible shaded frontages and not concentrated within exposed corridors. Primary schools should be kept near residential demand and have protected approach paths. Gymnasia and police centers should be easily accessible and visible, although their internal gains justify moderately situated interior placements. Residential buildings and polyvalent rooms can be used for completing disadvantaged edges because their internal gains are the lowest in the schedule.

5. Discussion

In BenGuerir, the three criteria of program relevance, accessibility, and cooling pressure cannot be combined without discrimination. A plan assigning civic uses only to central parcels would overvalue the centrality criterion. On the contrary, a plan relocating all high internal-gain functions to the edge would overvalue cooling pressure without respecting service reach and accessibility. The applied algorithm reconciles the two perspectives by letting each civic program retain its service importance while acknowledging its cooling load. The latter is important for this case, as the annual energy balance in the hot city is highly negative: cooling intensity is more than twice heating intensity.

A mixed-use building presents an interesting case of dual demands. Its $0\,\mathrm{m}^2$ to $150\,\mathrm{m}^2$ size constraint could suggest locating such facilities within compact clusters of commercial functions. However, as noted above, mixed-use buildings generate the highest internal gain of $65.28\,\mathrm{W\,m^{-2}}$, which implies distributing them across multiple shaded and accessible segments. This would provide for the best of both worlds, as such a decision would let the program maintain its accessibility and reduce the chances that the most visited part of the plan (i.e., an exposed commercial street) would generate the most cooling demand as well.

Primary schools constitute another interesting case. At $43.73\,\mathrm{W\,m^{-2}}$, they have the third-highest internal gain. However, unlike the gymnasium, police center, secondary school, and health center, which all require wider service distances, a primary school must always be situated close to residential demand. Thus, the best solution would be to keep it near residential neighborhoods and provide for safe, shaded access to it. This finding provides an answer to a practical planning challenge that would remain ambiguous without consideration of internal gain: to preserve everyday service while ensuring optimal thermal design.

Gymnasiums, police centers, and secondary schools present the third siting category. These facilities have relatively high internal gain of $55.05\,\mathrm{W\,m^{-2}}$ ($49.10\,\mathrm{W\,m^{-2}}$), and $45.52\,\mathrm{W\,m^{-2}}$ respectively. However, since these facilities operate within wider service distance of 2000 m compared to that of primary schools, they can be located in interiors rather than exposed urban edges. While the reach requirement would limit their placement options, it would enable their effective placement and would not necessarily require maximum centrality for proper accessibility.

The comparison of masjids and polyvalent rooms shows that equal service distances do not imply similar cooling pressures. Both of them are assigned to the neighborhood tier (1200 m). However, whereas the masjid has high occupancy-associated gain of $27.10\,\mathrm{W\,m^{-2}}$, the polyvalent room generates internal gain of $19.15\,\mathrm{W\,m^{-2}}$. In this sense, a masjid should be treated as an elevated civic space requiring additional comfort, and the polyvalent room as a less intensive community building suitable for shared use. Both of these considerations affect their placement in the plan.

The smallest internal gain of $18.98\,\mathrm{W\,m^{-2}}$ belongs to residential buildings. It does not mean that their thermal comfort is less important than that of the other facilities; it means that in comparison to other programs, the residential buildings can be positioned along exposed edges without excessive cooling demand penalties. As in the case of masjids, the residential building is an appropriate candidate to serve as a buffer for an exposed urban fabric.

The envelope parameter of the equation allows for the following insight. The window is much higher than the of walls and roofs. Thus, a facility having significant internal gain that is positioned on the exposed frontage would face the doubled burden of cooling. Not only the internal heat should be managed, but also the possible heat gained via conduction and solar gain through windows. The 0.25% mitigates the solar effect, but it still does not eliminate the need for shading and orientation.

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The importance of the background literature consists in explaining how the calculation relates to the problem of urban design and accessibility. Specifically, Hansen [13] and Litman [17] provide for understanding of the reason why some facilities must have close location with regard to residents. Geurs van Wee [10] explains the importance of legibility and accessibility in situating public functions. Lynch [18] describes the idea of street morphology as a basis for accessibility and legibility. Hillier and Hanson [14] further develop this idea to explain the need to connect spaces. Marshall [19] provides the definition of the urban civic core concept. Finally, Oke [20] discusses urban climate and explains the effects of internal and external factors.

The current calculation adds a new perspective on service reach: while accessibility remains an indispensable condition for proper functionality of civic spaces, their placement should take into account potential heat gain and cooling demand. The current results suggest allocating programs not equally but differently, taking into account their particularities and specific cooling needs. Ratti et al. [21], Erell [7], Allegrini et al. [1], Reinhart and Davila [22], and Ferrando et al. [8] provide relevant literature. In general, it confirms the importance of accessibility and urban morphology in shaping climate effects.

The presented algorithm is also valuable for urban design due to its transparency. All values used to estimate normalized gain can be traced to explicit criteria presented in Table 1, Table 2, and Table 3. Furthermore, the calculation of the coefficient can be traced back to the annual heat gain schedule. In terms of practical significance, the results would assist in reviewing the siting decisions made during the design phase and discussing them based on actual criteria rather than preferences.

The current results change the discussion of service equity. Service equity cannot be defined as locating every facility within its maximum service radius. Rather, it can be defined as allocating facilities within a radius while ensuring comfortable pedestrian access to them. As an illustration, a properly functioning primary school in a semi-arid environment cannot have too large access path because the child pedestrians would suffer under excessive heat stress. The same goes for a masjid and a mixed-use facility.

The results also demonstrate how to treat the centrality criterion. It can be used as a resource and not imposed arbitrarily on all facilities. Specifically, gymnasiums and police centers have the same service reach as residential and polyvalent functions (namely, 2000 m) but much higher internal gain ($45.52\,\mathrm{W\,m^{-2}}$, $49.10\,\mathrm{W\,m^{-2}}$). Thus, these facilities can be moderated within the plan, i.e., moved into less exposed parts of a semi-arid district.

The transparency of the calculation makes it useful for interdisciplinary design discussions. Urban designers can refer to the access and legibility terms; building energy specialists can discuss the cooling and internal gain terms; planners can verify the results by referring to the explicit criteria provided in the table. This legibility is essential because, at the earliest stage of siting, multiple design concerns must be negotiated. The calculation does not impose any decisions. However, it provides for their rational foundation.

The visual sequence presented above makes the same point as the mathematical and tabular arguments. The context view introduces the hot environment; the program cards demonstrate area, floor, and reach constraints; the normalized gain graph and the plot identify the gap between program priority and cooling demand; and the siting bands and program cards provide recommendations regarding allocation of the functions in question.

The current analysis has several limitations related to insufficient input data. Specifically, there is no geometrical data of the site, there is no information regarding the facade orientations, there are no hour-by-hour weather data, and finally, there is no detailed occupancy information for the facility types. However, these limitations do not affect the core argument of the calculation as it prioritizes cooling-relevant allocations. Furthermore, the results of the analysis would inform further simulation efforts. More specifically, the highest-gain functions along with exposed locations should receive additional attention.

It also implies the necessity of considering additional urban-design aspects in siting. In particular, it would be essential to design a good accessibility for a civic facility within the right allocation pattern. Otherwise, the result would be the same as with a poorly-designed allocation – heat-stressed users who would suffer due to high temperatures. Similarly, mixed-used spaces cannot provide for good commerce if they are not comfortable. Thus, the allocation decision must lead to a further street design.

6. Conclusions

The current BenGuerir schedule requires differentiation of the civic program allocation because of conflicting service reach and cooling demands. The current calculation indicates that a better solution would be to assign a differentiated allocation rather than a unified one. In particular, primary schools and selected mixed-use units must be situated centrally due to their proximity service reach (750 m). On the contrary, masjids and polyvalent rooms should serve the neighborhood tier (1200 m). As for the remaining programs, they can be located in interiors but not at the peripheries due to their longer reach. Finally, residential and polyvalent buildings can complete exposed edges due to their lower gain.

As far as the evidence is concerned, the current calculation identifies the most cooling-sensitive functions, namely, mixed-use facilities (65.28 W/m^2), gymnasium (55.05 $W\,m^{-2}$), police center (49.10 $W\,m^{-2}$), secondary school (45.52 $W\,m^{-2}$), and primary school (43.73 $W\,m^{-2}$). However, due to their heating-to-cooling ratio of 2.03, they should not be centralized at the periphery without considering shading, envelope control, and orientation. The fact that residential buildings and polyvalent rooms generate minimal gain does not imply that the corresponding facilities require no attention.

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