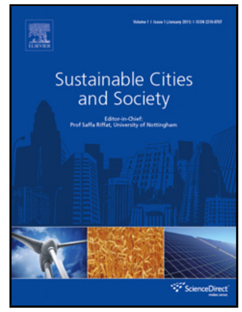

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PII: S2210-6707(17)31526-3
DOI: https://doi.org/10.1016/j.scs.2018.02.032
Reference: SCS 999

To appear in:

Received date: 8-11-2017
Revised date: 16-2-2018
Accepted date: 21-2-2018

A comparison study on space-use analysis techniques and proposal of a novel method for determining space needs in public facilities

MANUSCRIPT TITLE

A comparison study on space-use analysis techniques and proposal of a novel method for determining space needs in public facilities

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Highlights

- Public facilities are not spatially efficient
- Situational awareness on space-use in multiple public facilities is required
- Methods for space-use analysis are described and compared
- Novel, low-cost and non-expert method for determining space needs is proposed
- The method application is explained and results presented for various facilities

Abstract

This paper deals with inefficient space management of public real estate resulting in discrepancy between the amount of space required for provision of public services and the amount of space that is available. This situation causes either waste of resources, in case of underused spaces, or affects quality of service if the space is overused. To address this issue, this paper compares different methods for space-use analysis and discusses their suitability for public facilities. It also proposes a novel, activity-centered method for defining space needs. The paper contributes to the state of the art in the following ways: It demonstrates that generally used methods for space-use analysis are not appropriate for public buildings due to their cost, complexity and building-centered approach. Moreover, it reveals that methods used in the private sector cannot be simply copied to the public one. However, its biggest contribution is proposal of a new, low-cost and activity-centered method for determining space needs that can be applied for multiple public buildings of different purposes.

Key words

space-use; space needs assessment; space efficiency; public facilities optimization

1. Introduction

Public facilities should provide adequate amounts of space to meet the needs of services that are carried out within. It is not an easy goal to achieve because, in the course of a facility lifecycle (usually programmed for at least 50 years), the changing environment can alter the spatial needs, while the amount of space available remains constant. It is important to stress that many facilities that are currently used are historic buildings designed for purposes other than those they serve nowadays (Stanford University 2009). In consequence, there are many examples of services offered in facilities that are either too small or too large. Neither of these situations is desirable. The first one affects service quality by preventing it from developing its full potential, while the latter satisfies service spatial requirements fully but is not efficient economically, since excess space can be considered as a waste of resources. For this reason, buildings must respond to the changing environment by constantly adapting their space-use to the new functional demands (Kuipers, Tomé, Pinheiro, Nunes and Heitor 2014).

Space is one of the most valuable and essential resources of any organization (Zijlstra, Mobach, van der Schans and Hagedoorn 2014). It has to be managed systematically and efficiently because is expensive to buy and costly to maintain (SMG 2007; Wiggins 2014). According to Cowan (1963) most human activities takes place at $20m^2$, but even areas as small as 2,5 m^2 have been found sufficient for various activities. Therefore, significant savings may be rendered by responsible, and adjusted to the needs, space use.

A simple cost calculation can illustrate this on the example of the 68 public facilities in Girona, Spain. The current average cost per square meter of constructed floor space in Girona is € 2 119 (December 2017) (Habitaclia 2017). In addition, the average value of rented square meter is € 9.18 per month (December 2017) (Habitaclia 2017). Optimizing only $10m^2$ (which in the authors opinion is a far underestimation) in every facility would generate € 1 440 920 in savings – an approximate equivalent of the construction cost of a small-size facility. At the same time, if the optimized surface were leased, the earnings could be in the range of € 74 909 per year. Of course, the additional costs of the surface conversion to new uses would need to be included but, compared to the possible profits, this cost would be rather insignificant. Taking into account that this calculation has been made for a small-size city (approx. 100 000 inhabitants), the benefits may be much higher if such optimization were applied in large cities. Releasing unnecessary space allows saving not only the equivalent of its market value but also 100% of the operating costs for that space (FMLink n.d.). This is crucial because maintenance and operating costs calculated over a facility's lifecycle go far beyond the value of its design and construction (Kelly, Hunter, Shen and Yu 2005; Atkin and Brooks 2009). For this reason, the re-allocation of unused space is one of the keys to more flexible planning and space efficiency (SMG 2006a). Improper space management, in extreme cases, may result in creation of urban voids - unused, abandoned or in-between spaces among public and private realms (Lee and Lee 2015).

In the private sector many retail and office buildings are occupied for no more than 50% even at the busiest time of day (NCTC 2004). Nevertheless, there are numerous solutions for space management in the private sector including facility management (FM) and building information modelling (BIM) tools. Unfortunately, solutions created for the private sector cannot be simply copied and applied to the public one (Walley 2013). There are examples of BIM adoption for public facilities, as described by Gurevich, Sacks and Shrestha (2017) but they are still very uncommon. This is because the public sector operates differently in many ways such as in terms of priorities, costs, capacities, and outputs (Spicker 2009). Moreover, the management of public facilities has to take into account a significant variety of uses since public buildings have many different purposes.

Determining utilization for each building individually is very costly and difficult technically since public sector have become the largest property holder in the world (Deloitte, n.d.).

In consequence there is little awareness about the space resources available in numerous public facilities. However, space scarcity is more frequently detected because usually service directors complain about it. Conversely, space excess is not so easy to detect since people's needs are unlimited, and service directors usually are not willing to report on having too many resources unless they are rewarded for it. Therefore, the spatial requirements of a local government service must be determined through the use of a more objective, quantitative method.

This method has to be general enough to evaluate buildings of different uses at low cost (including cost of input data) to provide a general image of space needs at the scale of the city. This image has to indicate buildings with highest discrepancies between space supply and demand, narrowing the focus of the future, more in depth, analysis and optimization. To this end, the purpose of this paper is to describe and compare different approaches of space-use analysis and propose alternative method for defining space needs focused on users' activity to decrease the mismatch between space demand and space supply in public facilities.

2. Ways and means of space-use analysis

There are numerous approaches for space-use analysis that can be used depending on the context, purpose, and available resources. Determining factors for this analysis are: the acquisition of data on users' behaviour (their number, type of activity, duration, etc.) and the capacity to process this data, both of which generate a significant cost.

Observation of users' behaviour is the simplest and most natural method. An attentive observer can draw conclusions on how space is being used and indicate areas of improvements. Obviously, this method is applicable only to small and uncomplicated buildings. It is also very prone to subjective interpretation of the observer.

Facility benchmarking compares facility performance against other buildings of similar characteristics. The most common metric is gross area per occupant which does not require data on users' behaviour. However, facility benchmarking should fulfil at least two prerequisites: it has to contain an inventory of analogous, comparable buildings and it has to be regularly updated (Reichelt 2005). The result does not provide specific information about space-use, but instead indicates whether the building performance is higher or lower in comparison with other, similar buildings.

On the other extreme there are complex approaches for rigorous and extensive space-use management. Computer aided facility management is a set of tools for very comprehensive building monitoring and control. It operates on detailed physical building data combined with information on users' activities. The high precision of this solution is reflected in its cost which encompasses software, hardware and qualified human resources. For this reason, only few public administrations can afford such an investment.

Space syntax is a human-focused approach investigating users' interactions with space. It requires a combination of both quantitative and qualitative tools to capture correlations between space configuration and users´ behaviour. It can be applied to analyses specific buildings or group of buildings as a network of interactions (Craane 2013). Space syntax is a very potent instrument, however due to its complexity it is rather much more in the interest of scientific research than a tool for space management in the city.

Thus, efficient space management in a very specific context of public buildings requires an approach which is simple, inexpensive and uniform, allowing its application to a variety of buildings of different types. To his end the following subsections describe in more details methods of space-use analysis potentially useful for the public sector and proposes alternative method focused on users' activities.

2.1. Guidelines approach - facility comparison with building design standards

The guidelines approach is a method for evaluating space-use by comparing a facility with relevant design standards or construction norms that define area measures in relation to the number of users or reference population. Such a comparison may be done with regard to an entire facility or to specific facility areas.

The guidelines approach is an inexpensive and easy to apply tool for space-use analysis. However, it has also several limitations. Firstly, there are no design standards for all types of public buildings. Existing norms refer only to some well-standardized types of facility such as schools, health care centers or libraries. Yet there are many facilities that are difficult to standardize because they are programmed in an ad-hoc manner to fulfill the current needs of local communities. Secondly, facility design standards are context-related and take into account the unique characteristics of the region they are designed for. Consequently, a standard developed for one area may not be suitable for another. Thirdly, design standards assume a strong association between service and facility. They are focused on buildings and do not reflect service perspectives which makes them helpful in the evaluation of single-service facilities. However, in practice, it is not uncommon that numerous services or activities are offered under one roof. These supplementary activities are not included in standards which makes the guidelines approach unreliable for multi-service facilities. Fourthly, design standards can only be successfully applied to evaluate space-use in recently built facilities that have been constructed for a specific purpose. However, their utility is very limited in the case of older, especially historic, buildings that usually have been repurposed, even several times, since their construction. In fact, about 40% of Europe's building stock is more than

50 years old (Becchio, Corgnati, Delmastro, Fabi and Lombardi 2015). For such kinds of building a comparison with standards may not be reliable. Finally, guidelines approach has relatively low precision. This is because it takes into account only the physical characteristics of a building – a fraction of the information that is needed - without considering information about users' activities, their type and duration, all of which greatly affect space-use (Kim 2013).

2.2. The UFO method

The space utilization rate is a measure proposed by the UK National Audit Office to evaluate space-use in education buildings. This method however, could also be applied to other types of facilities. The space utilization rate calculus is also called the 'UFO' method (Abdullah, Ali and Sipan 2012) because utilization (U) has two components - frequency (F) and occupancy (O). The first refers to the number of hours the space is in use, while the latter refers to the number of users. The UFO method formula has the following form:

$$\textbf{U}\text{tilization rate} = frequency * occupancy$$

$$\textbf{F}\text{requency} = \frac{number\ of\ hours\ a\ room\ is\ in\ use}{total\ room\ availability}$$

$$\textbf{O}\text{ccupancy} = \frac{avarage\ group\ size}{total\ room\ capacity}$$

(NAO 1996)

The UFO calculus provides accurate information on the degree of utilization of specific building rooms or spaces. The method abolishes the strong relationship between facility and service, and focuses on measuring the utilization rate for specific building areas. It is therefore appropriate for non-standard and multi-service facilities. However, the usefulness of this method is limited. For buildings in which activities of different kinds takes place, and the number of users is random, the number of hours the space is in use, as well as the average group size, may be difficult to determine, and consequently the utilization rate will be problematic to establish.

3. Method for determining space needs

The Method for Determining Space Needs (MfDSN) is an alternative to the above-mentioned ones. Its novelty is based on the service/activity approach leading to conceptual separation of activities from spaces where they take place. This allows to determine how much space is required for each activity. The result is subsequently compared with facility area measures to obtain information on space utilization. A distinguishing advantage of this method is that considering space needs of all activities allows to obtain explicit images of space demand, while other methods that focus on measuring specific rooms, may not capture the space needs precisely because one activity may take place in various spaces and one space may be allocated for various activities of different kinds. Thus the Little's law has been used to determine the average number of users of every considered activity. In consequence, the method for determining space needs is especially useful in terms of activities carried out on an irregular basis, and those with regard to which group size is difficult to determine. The method consists of five steps that are described in sections 3.1. – 3.5.

3.1. Service decomposition

Service decomposition is necessary to identify all types of activities that take place in the facility under consideration. A service can be defined as a piece of work performed for/on behalf of the citizen. Each service is composed by a number of activities identified by their duration, the number of participants (users) and the area per person factor.

3.2. Determining number of users present at any moment

The number of users taking part in every activity may be random and change frequently. For this reason, the average number of users present at any moment has to be determined. To this end, a facility can be considered as a queuing system where users arrive, spend some time, and leave (De Sanctis, Kohler and Fontana 2014). Therefore, to determine the average number of users present at any moment, Little's law can be applied: $L = \lambda W$, where the expected number of units in the system (L) is equal to the expected time spent by a unit in the system (W) multiplied by the expected rate of arrivals to the system (λ) (Little 1961). In the case of public facilities, the system is represented by activities that take place in the facility, and the units are the participants in these activities.

It is important to mention that some activities require a designated space that cannot be used for other purposes, even if it is vacant (Kim, Rajagopal, Fischer and Kam 2013). For this kind of activity, it has to be assumed that the number of users is equal to the number of workstations and is constant. Such a situation may occur, for example, in an office area where each employee has his/her own workplace that cannot be used by any other person, even if unused.

3.3. Determining space needs

The space required for each activity can be determined by multiplying the number of users present at any moment by the appropriate area per person factor. The value of this factor can be extracted from building standards, it can be established individually for a particular case, or can be derived from other norms similar to the desired ones.

To determine the total space needs of the service or services offered in the evaluated facility, all activities have to be taken into account. Thus, the cumulative space demand (S) for a determined number of activities (n) can be calculated as a sum of the space needs of all activities, as follows:

$S = \sum_{i=1}^{n}(number\ of\ users * area\ per\ person\ factor)$

The result is the total average number of square meters required at any moment. However, the number of square meters needed is representative only for activities with a roughly steady number of users. In the case of occasional activities such as concerts or other cultural events, which involve a high concentration of people for short periods of time, this would not be a representative measure. For this reason, representing results in terms of utilization is more reasonable.

3.4. Facility decomposition

A comparison of space needs with facility area requires a facility to be decomposed. The first level decomposition divides the facility net room area into primary, amenity, circulation and technical areas according to the UNE-EN 15221-6 standards (BS EN 2011). Subsequently, for determining the degree of utilization, only the primary area is taken into account, since other types of areas have only a supportive function. However, the proportions between these areas may provide valuable information indicating potential inappropriate space assignment. For instance, according to GSA (2012) the circulation area should account for 28-38% of the building net usable area in office buildings. Thus any deviation from this range should be investigated.

The second level of decomposition divides the primary area into particular rooms or spaces to which activities are allocated. In this case analysis is conducted at the activity-space level, while the previous one was at the service-facility level (Figure 1).

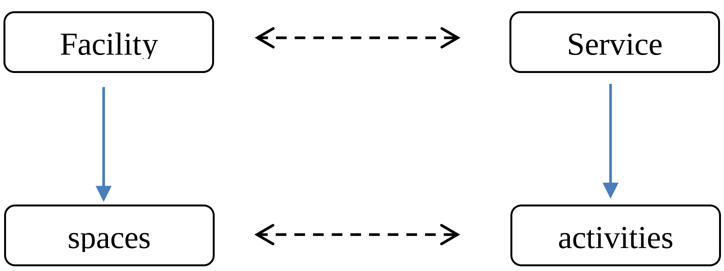

FIGURE 1. TWO LEVELS OF DEPENDENCY IN FACILITY DECOMPOSITION: SERVICE – FACILITY AND SPACES - ACTIVITIES.

As depicted in Figure 1, the association between service and facility can be transferred to the lower level which defines a service as a collection of activities and facility as collection of spaces.

3.5. Determining utilization rate

The utilization rate expresses space-use as a ratio of the amount of space needed to the amount of space that is available. This can be calculated for particular facility spaces (rooms) or at the scale of the entire facility. The first case requires an activity to be mapped to the appropriate space or room in which it takes place. However, in practice, correlating activity with space may be problematic because an activity may be carried out in various rooms. In such cases utilization can be calculated at the level of the entire facility by comparing cumulative space demand with facility primary area.

4. Case study

The methods described in Sections 2 and 3 have been tested and compared using the example of a youth social center facility 'L'Estació Espai Jove' located in Girona, Spain. This facility is a historic building that has been repurposed and adapted for the needs of the youth social service. Data concerning users and their activities has been extracted from an annual report (Ajuntament de Girona 2014). The data has been normalized to annual values for the sake of consistency and missing information has been supplemented or estimated based on interviews with the youth center personnel. The entire dataset is presented in Table 1.

TABLE 1. DATASET DESCRIBING YOUTH CENTER FACILITY AND ACTIVITIES CARRIED OUT IN YEAR 2014.

Facility	Service

Area type	Room name	Area (m^2)	No. of hours available	Activity name	Require designated space?	No. of uses	Activity duration time (h)	No. of activities	Area/ person factor (m^2/pers.)
Primary	Consultation	35.65	1940	Youth consultation	No	5326	888	1775	10
	Multipurpose	359.15	3331	Courses	No	519	304	69	2
				Workshops	No	544	56	18	5
				Activities of external entities	No	875	1006	250	2
				Self-activities	No	6325	1265	2530	2
	Office	73.8	2024	Administration	Yes	10	Full time	253	10
	Unused space	13.9	3331	Null	Null	Null	Null	Null	Null
Amenity	Restrooms	14.15							
Circulation	Entrance & reception	51.75							
Technical	Storage	42.25							

The first two columns of Table 1 represent facility decomposition. The first of them divides facilities into four area types, while the second specifies particular rooms or spaces. The third column contains area measures for each room, and the fourth one, the annual number of hours during which the room was available.

The following part of the table characterizes service. Consequently, values are provided only for the primary area. This is because the amenity, circulation and technical areas have only a supporting function. Column five contains the names of activities and six states as whether or not the activity requires designated space. Column seven provides the annual number of uses. This is important to differentiate from the number of users, because each user may take part in an activity several times. Column eight contains the annual duration time of each activity, while column nine contains the number of activities (events) over the course of the year. Finally, the last column specifies the area per person factor. This is a minimum amount of space that should be guaranteed for every participant.

Moreover, the following activities taking place in the youth center facility have been identified: youth consultation that allows the adolescence to share their doubts with trained professionals, ask questions and get information; courses and conferences on diverse themes such as ecology, energy-saving, job finding, etc.; workshops, such as theatre, knitting, bike repairing, etc.; activities organized by external entities in the form of different institutions based on space leasing agreements; self-activities involving the individual activities of the users, such as self-study, reading, searching the web, etc.; and administration – a back office activity related to the day-to-day managerial and organizational tasks of the center. This dataset has been used to test and compare different methods for space-use analysis in Sections 4.1 – 4.3.

4.1. Guidelines approach

To exemplify the guidelines approach for space-use analysis, all the rooms of the youth center facility have been compared with the standard for social services (20,000 < reference population < 50,000) (Serveis socials 2017). The results of this comparison are presented in Table 2.

TABLE 2. COMPARISON OF THE YOUTH CENTER FACILITY WITH DESIGN STANDARD FOR SOCIAL SERVICES.

Area type	Real area measures (m^2)	Area values from standard (m^2)	Real – standard (m^2)
Entrance and Reception	51.75	15	36.75
Office area	73.8	154	-80.2
Information and consultation area	35.65	125	-89.35
Restrooms	14.15	24	-9.85
Storage	42.25	20	22.25
Multipurpose area	359.15	Not included in standard	359.15
Unused space	13.9	Not included in standard	13.9
TOTAL:	590.65	338	252.65

The first finding from Table 2 is that it is hard to establish relationships between all facility areas and those listed in the standard. The restroom, office and consultation rooms are too small, while reception is too large in terms of the standard. In addition, multipurpose and unused spaces cannot be compared because such area types are not specified in the standard. Thus, specific areas cannot be directly compared, but comparison can be done at the scale of the entire facility by considering the total value provided by the standard, as the amount of space required for service provision. This indicates a surplus of 252.65m^2. The proportion of total real area measure and total area defined in the standard ($\frac{338\text{m}^2}{590.65\text{m}^2}$) result in rate of 0.572250 (≈57.2%).

4.2. The UFO method

This method can be used to determine the utilization rate for specific facility rooms where core activities take place. In the case of the youth social center, four rooms (spaces) have been considered: multipurpose, consultation, administration and unused space and the utilization rate calculated in the following subsections:

4.2.1. Utilization rate of multipurpose space

The utilization rate has been calculated according to the formula presented in Section 2.3. First element is frequency expressed as a sum of duration times of all activities that take place in the multipurpose space divided by the number of hours the space is available. Thus, the frequency = $\frac{number\ of\ hours\ a\ room\ is\ in\ use}{total\ room\ availability\ (timetable\ week)} = \frac{304+56+1006+1265}{3331} =$ 0.789813 (≈ 79%).

Occupancy calculus requires two components: average group size and room capacity. The average group size for four types of activity that take place in multipurpose space has been calculated as a sum of the number of uses divided by the sum of activities, as follows: $\frac{number\ of\ uses}{number\ of\ activities} = \frac{519 + 544 + 875 + 6325}{69+18+250+2530}$ = 2.88 participants per activity on average. Room capacity depends on the area per person factor. Its average value has been determined for 2.75 m^2/person. Hence room capacity is equal to the space area divided by the area per person factor, as follows: = $\frac{359.15}{2.75}$ = 130.6 persons. Subsequently, the values of both components have been substituted into formula as follows: Occupancy = $\frac{avarage\ group\ size\ (person)}{total\ space\ capacity\ (person)} = \frac{2.88}{130.6}$ = 0.02205 (≈2.2%).

Finally, the utilization rate of the multipurpose space = 0.789813*0.022052 = 0.0174 (≈ 1.7%).

4.2.2. Utilization rate of consultation space

The utilization rate of the consultation space has been determined in a similar way, substituting values from Table 1 to the following formulas:

Frequency = $\frac{number\ of\ hours\ a\ room\ is\ in\ use}{total\ room\ availability} = \frac{888}{1940} = 0.4577\ (\approx 46\%)$

Occupancy = $\frac{number\ of\ uses}{number\ of\ activities} = \frac{3}{3.565} = 0.8415\ (\approx 84\%)$

Utilization =$0.4577 * 0.8415 = 0.3851\ (\approx 38.5\%)$

4.2.3. Utilization rate of office space

Office space is a designated space where no other activity can be performed even if the workstation in unoccupied. For this reason, the number of hours that the space is used is equal to the total number of available hours, thus the frequency = 100%. Consequently, occupancy = utilization, as shown below:

Occupancy = $\frac{10}{7.38} = 1.35501\ (\approx 135.5\%)$

Utilization = 1 $*$ 1.35501= 1.35501 (≈135.5%).

4.2.4. Total facility utilization rate

The results obtained using the UFO method indicate that the utilization of multipurpose space is very low, at only 1.7%. The utilization of consultation space is moderate – 38.5%, and the administration space turned out to be overused - 135%. There is also unused space with utilization rate equal to 0%. Thus the general facility utilization is a weighted mean calculated as follows $= \frac{0.789813 * 359.15 + 0.3851 * 35.65 + 1.35501 * 73.8 + 0 * 13.9}{359.15 + 35.65 + 73.8 + 13.9} = 0.2486$ ($\approx$ 24.9%).

4.3. Method for determining space needs

This method has been described and tested on the same dataset. The step-by-step procedure is exemplified in the following subsections.

4.3.1. Service decomposition

The youth social service offered in the 'L'Estació Espai Jove' facility has been decomposed to the following activities: youth consultation, courses, workshops, administration, activities carried out by external entities, and other self-activities.

4.3.2. Determining number of users present at any moment

The average number of users present at any moment can be determined by using Little's law (L = λW). The average time spent on activity (W) can be obtained by dividing the activity duration time by the number of activities, as presented in Table 3.

TABLE 3. AVERAGE TIME SPENT ON ACTIVITY AND ITS COMPOUNDS.

Activity name	Activity duration time (h)	Number of activities	Average time spent on activity (W)
Youth consultation	888	1775	0.50
Course	304	69	4.40
Workshop	56	18	3.11
Activities of external entities	1006	250	4.02
Self-activities	1265	2530	0.5

The average rate of arrivals (λ) can be obtained by dividing the number of uses by the number of hours the space was available (De Sanctis, Kohler and Fontana 2014), as presented in Table 4.

TABLE 4. RATE OF ARRIVALS AND ITS COMPOUNDS.

Activity name	Number of uses	Number of hours available	Rate of arrivals (λ)
Youth consultation	5326	1940	2.74
Course	519	3331	0.15
Workshop	544	3331	0.16

Activities of external entities	875	3331	0.26
Self-activities	6325	3331	1.9

The results of this calculus are presented in Table 5. Administration requires a designated space; therefore, the number of users present at any moment is equal to the number of administrative staff (workstations).

TABLE 5. NUMBER OF PARTICIPANTS PRESENT AT ANY MOMENT FOR EACH ACTIVITY.

Activity name	Rate of arrivals (λ)	Avg. duration (W) (hours)	Avg. number of users (λW)
Youth consultation	2.74	0.50	1.37
Course	0.15	4.40	0.66
Workshop	0.16	3.11	0.5
Activities of external entities	0.26	4.02	1.04
Self-activities	1.9	0.5	0.95
Administration	Requires designated space		10

4.3.3. Determining space needs

For the sake of determining space needs, the area per person factor has to be assigned to each activity. The value of this factor has been extracted from Spanish Building Standard for Fire Security in Buildings (Ministerio de Fomento 2010) and multiplied by the number of users present at any moment.

TABLE 6. AMOUNT OF SPACE REQUIRED FOR EACH ACTIVITY.

Activity	Avg. Number of users	Area per person factor (m^2)	Space needs (m^2)
Youth consultation	1.37	10	13.7
Course	0.66	2	1.32
Workshop	0.5	5	2.5
Activities of external entities	1.04	2	2.08
Self-activities	0.95	2	1.9
Administration	10	10	100
		Total:	121.50

As shown in Table 6, the total average amount of space needed at any moment is ≈ 121m^2. This value needs to be compared with the facility primary area, for which facility decomposition is necessary.

4.3.4. Facility decomposition

The decomposition of the youth center facility is presented in first three columns of Table 1.

4.3.5. *Determining utilization rate*

The utilization rate for the entire facility has been calculated as a proportion of the number of square meters needed at any moment to the number of square meters available (the primary area): $\frac{121.50}{482.5} = 0.251813 \approx 25.18\%$. In addition, for the purpose of comparison, the utilization rate has been also determined for particular facility spaces. As shown in Table 7, all spaces turned out to be underused, with the exception of office space which is overused.

TABLE 7. UTILIZATION RATE OF FACILITY SPACES.

Room	(m^2)	Activity	Space needs (m^2)	Utilization rate %
Multipurpose	359.15	Course, Workshop, Activities of external entities, Self-activities	7.93	2.2
Consultation	35.65	Youth consultation	13.73	38.5
Office	73.8	Administration	100	135.5
Unused area	13.9	Null	Null	0

4.4. *Space-use evaluation of numerous public facilities*

The purpose of the MfDSN is to evaluate numerous public facilities distributed over a city area. Thus this method has been applied to evaluate five public facilities located in Girona: Cultural Center 'Marfa', an employment office, a habitat office, Migdia School and a youth social center. The facilities were selected based on their location (located in different districts) and the diversity of the services offered within. The utilization rate for each facility has been determined according to the procedure described in Section 3 with one difference – target utilization has been established.

Target utilization defines the maximum achievable utilization rate – a value for which space is used efficiently on the one hand, and does not negatively affect working conditions on the other. Setting target utilization improves legibility and helps interpret results. This is because a utilization rate equal to 100% is not feasible in practice (NAO 1996; SMG 2006b). The value of the maximum achievable utilization varies, depending on the type of facility. According to (SMG 2006b), in buildings consisting mainly of office space, 85% can be achieved. Pennanen (2004) states that a utilization rate of 80% for schools may be too high and could result in space shortage. On the other hand, NAO (1996) claims that a utilization rate of 50% may be challenging. In addition, HEFCE (2000) defines a good utilization rate as being equal to or greater than 35%. This indicates that a utilization target depends on the type of service (activities) and is very subjective. Thus, for the purposes of this exercise, target utilization has been set at 70%, and the absolute values have been converted accordingly (70% = 100%). In this way results above 100% indicate over-utilization and those below, under-utilization. The final values have been represented spatially in an easy-to-interpret manner in Figure 2. This allows an organization to obtain awareness about space-use in all its facilities and helps to prioritize future actions, since facilities where utilization diverges strongly from the optimal should be improved in the first instance.

FIGURE 2. VISUAL REPRESENTATION OF SPACE UTILIZATION IN VARIOUS PUBLIC FACILITIES.

The youth social center is characterized by a very low utilization rate. This could be improved by either introducing additional activities or releasing space. On the other hand, the utilization of the employment office exceeds 100% which, in the authors' opinion, is especially hazardous since overused building may affect users' comfort, working conditions and general quality of service. For this reason, it should be given a priority for optimization and in consequence has been marked in red.

Overused buildings can be optimized either by delegating some activities to other facilities or by improving scheduling such as by extending opening hours. The utilization of the Cultural Center Marfa is relatively good, but still not optimal. Finally, the utilization of the Habitat office and Migdia School are close to optimal, and therefore these facilities should have low priority for with regard to modifications.

5. Results

In Section 4, different methods of space-use analysis have been tested on the same dataset. The results have been summarized in Table 8.

TABLE 8. RESULTS OF THE SPACE-USE ANALYSIS OBTAINED BY DIFFERENT METHODS.

Room	Methods		
	Guidelines approach	UFO method	Method for determining space needs
Multipurpose	null	1.7%	2.2%
Consultation	350%	38.5%	38.5%
Office	200%	135.5%	135.5%
Unused area	0%	0%	0%
Total:	57.2%	24.9%	25.2%

In terms of these results, the guidelines approach provided a relatively high general utilization rate (57.2%), while in relation to the amount of space defined in the standard to the real measures of consultation and office space, there is a strong degree of over-utilization (350% and 200% respectively). Multipurpose and unused space are not specified in the standard, making comparison of specific facility spaces impossible. The precision of the results can be influenced by various factors. First of all, the guidelines approach does not take into account information on user activity. It compares space measures without considering how they are used. Moreover, the standard is defined for a wide range of reference population (20,000 < reference population < 50,000). In addition, the youth center facility is a historic building that is harder to adapt to current needs than is the case with modern facilities for which the standard was designed.

The UFO method is characterized by higher precision than guidelines and benchmarking because it takes into account information on users' activities in addition to facility physical dimensions. The utilization determined for specific rooms showed a very low rate for multipurpose, and moderate for consultation space (1.7% and 38.5% respectively). On the other hand, office space turned out to be overused (135%). Moreover, the average utilization rate obtained for the entire facility is 24.9%.

The method for determining space needs provided very similar results to the UFO method. There is however a slight decimal fraction difference, a result of the use of an averaged value of the area per person factor in the UFO method as used to determine the capacity of the multipurpose area. Regardless of this detail, the results of both methods can be considered as equivalently correct.

6. Discussion and conclusions

The decision making process with regard to space management in the case of public facilities requires an inexpensive, non-expert and easy-to-use method for determining space utilization in multiple facilities. Methods that are potentially useful for this purpose have been described, tested and compared. The outcomes of this experiment are summarized in Table 9.

TABLE 9. SUMMARY COMPARISON OF DIFFERENT METHODS FOR SPACE-USE ANALYSIS.

	Guidelines approach	UFO method	MfDSN
Scope	Entire facility/ facility areas	Facility areas	Entire facility/ facility areas
Type of facilities	Public and private	Public and private	Public and private
Includes users' activity	No	Yes	Yes
Focus	Building-centered	Building-centered	Service/activity- centered
Building size	Any size	Any size	Any size
Amount of required data	Low	Medium	Low
Precision	Medium	High	High
Cost	Low-cost	Low to medium	Low-cost

The guidelines approach is a low-cost and simple solution for space-use analysis which makes it potentially suitable for use in the public sector. However, the usefulness of this method is limited to well standardized facilities such as schools. However, many public facilities are not typical and finding appropriate standards for them may be problematic. Thus the guidelines approach can be considered a good solution for space-use analysis only for some, but not all, types of public facilities.

The UFO method allows a determination of the utilization rate for specific rooms or building areas. Unlike the benchmarking and guidelines approach, this method considers information about users' activities which makes it much more accurate. It also provides information on the frequency and occupancy as components of utilization. This tells us whether the number of users or time they spend have a stronger impact on utilization – potentially useful information in the event of rearrangement. The data required concerns average group size, room capacity, as well as the number of hours in use. The main limitation of this method is the strict relationship between room and activity. This makes it advantageous for rooms linked to a specific type of activity (such as classrooms), but its application is problematic for spaces with multiple activities of different kinds.

The MfDSN can be applied to defining the utilization of particular spaces (as with the UFO method) but it is especially beneficial for determining space-use at the scale of the entire facility. What distinguishes this method from the others is the service/activity focus which allows us to define the amount of space that is required. This makes it especially useful as a planning tool and, if used for evaluation purposes, is particularly convenient when activities of different kinds take place in the same room, or one activity is carried out in various rooms (an issue with which other, building-focused methods do not deal well with). However, the main advantage of this method is that it can be used to determine the utilization of the entire building without analyzing in detail the correlation between activities and specific spaces. This significantly decreases the amount of data required for evaluation which translates to lower cost when various buildings have to be evaluated. This, combined with simplicity, makes this method low-cost, non-expert and, consequently, more advantageous for space-use analysis on multiple public facilities than the other techniques. However, because the method reuses statistical data encompassing larger periods of time, the resulting average values simplify the reality. Figure 3 depicts the average distribution of users of the Marfa cultural center during its opening hours (A). In fact, such a steady state is hardly likely to be achievable under normal circumstances. It could be relevant only for activities requiring a designated space such as administration. However, in reality, the distribution of users is unequal, and for some activities can be considered random (e.g. visiting a library), as it has been depicted by Google popular times which uses the location of android mobile devices (B).

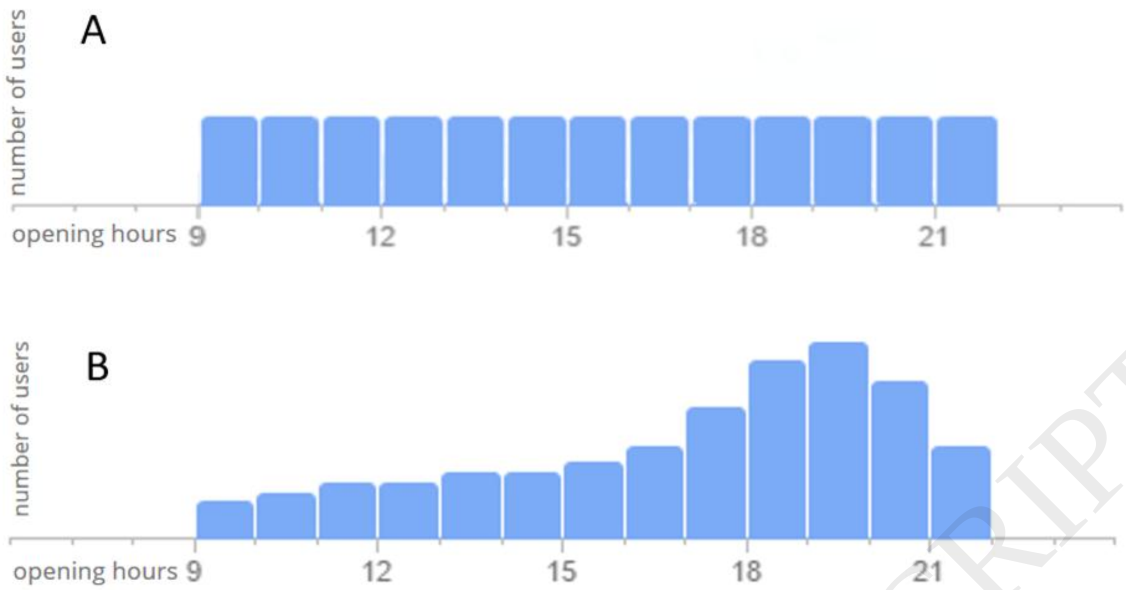

FIGURE 3. COMPARISON OF AVERAGE NUMBER OF USERS IN CULTURAL CENTER MARFA DURING THE OPENING HOURS (A) AND DISTRIBUTION OF USERS DURING OPENING HOURS FROM GOOGLE POPULAR TIMES (B).

A precise distribution of the users during facility opening hours is still costly to obtain because it requires application of sensors and technology to monitor users' behaviour. However, increasing popularity of ubiquitous computing provides new possibilities also for the purposes of space-use analysis. In this context crowdsensing technologies have a huge potential. Crowdsensing uses mobile devices of collectivity to acquire useful data. This concept treats all building users as living sensors (human sensor). This means that data on user's activity (place, time, behaviour) can be collected without their active participation by means of sensors generally incorporated in mobile devices, such as GPS and Wi-Fi connection. This significantly reduces investment in monitoring hardware. However, it entails a very important and still controversial issue of privacy, for which crowdsensing has to be applied carefully respecting user's anonymity.

Another remark worth making is that utilization is determined for a particular facility only during its opening hours. However, many public buildings potentially could also be used after hours. This is especially relevant for buildings with short opening hours and those that are unused for longer periods, such as schools during summer holidays.

Finally, the most important concern is that determining space needs and the utilization of public facilities does not increase space efficiency by itself. Situational awareness on space-use is crucial, but it is only the starting point for future decision making. The enhancement of space-use efficiency requires action. These actions may lead to a release of space in underused facilities, or the introduction of additional activities to make better use of available spatial resources.

In this way the space can be reused and the building can be repurposed into multifunctional (multiservice or multipurpose) facility. Multi-purpose facility is a building which combines different services under one roof, and permits more than one activity to take place at the same time and in the same location (Gupta and Gupta 1988). It also reduces the amount of urban land necessary for the provision of public services (Marsal-Llacuna, Leung and Ren 2011). Multifinctional building can combine different types of activities both public and private. In recent times, the growth of co-working spaces has been recorded. This phenomenon allows a very flexible use of even small amounts of space because a shared workplace is utilised by different individuals (mostly knowledge workers) renting their workplace for certain amount time. This implies that the same workstation can be used by more than one person during the day (Gandini 2015).

On the other hand, the performance of overused facilities can be improved by delegating non-core activities to other, less occupied buildings. Such decisions however need to be discussed individually for each case, and contextual constraints will have to be taken into consideration. Only the complete process from determining space needs to taking a final decision may minimize overused and underused spaces, and make public facilities more sustainable and economically efficient.

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