DECISION SUPPORT FRAMEWORK FOR SPACE-USE OPTIMIZATION AND ARRANGEMENT OF PUBLIC SERVICES

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Universitat de Girona

PhD Thesis

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DECLARE

The work entitled *Decision support framework for space-use optimization and arrangement of public services p*resented by Robert Rusek to obtain the degree in Doctor of Phylosophy has been developed under our supervision.

For all intents and purposes, we hereby sign this document.

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Girona, April 2017

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PhD research involves advanced academic work, but it is also involving a great deal of creativity. Adam Grant in his TED talk The surprising habits of original thinkers describes the six steps of the creative process:

1. This is awesome
2. This is tricky
3. This is crap
4. I am crap
5. This might be okay
6. This is awesome

I would like to express my utmost gratitude, especially to those who supported me when I was balancing between steps three and four. This work would never be accomplished without you!

Publications

The presented thesis is a compedium of the following research publications:

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In addition, the research involves the following:

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Acronyms

ASF	assignable square feet
ASM	assignable square meters
BIM	building information modelling
BPM	business process modelling
BVG	business value granularity
CAFM	computer aided facility management
FM	facility management
IxD	interaction design
MfDSN	method for determining space needs
MSF	multi-service facility
NIA	net internal area
POE	post occupancy evaluation
PPPP	public-private-people partnership
RFID	radio frequency identification
SA	situational awareness
SD	service design
SOA	service oriented architecture
SS	service science
UFO	utilization, frequency, occupation

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Discussion

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Abstract

Public services constitute a specific interface between citizens and public administration bodies. This unique touch point permits both groups to interact and engage in their proper functioning with regard to different aspects such as health care, education, culture, etc., all of which are indispensable for society's well-being. All public services require facilities – buildings in which they can be delivered, such as hospitals, schools or museums. For this reason, public services and facilities are two integral components of a functioning city that should be well matched. In particular, facilities should provide a sufficient amount of space to support all such service activities. Every facility has a specific physical space that rarely alters during the building's lifecycle. On the other hand, every service has specific space requirements. However, these requirements are the subject of constant change associated with economic, political, social and demographic fluctuations that continuously impact on the service in question.

These circumstances result in maladjustment between the amount of space available in the facility on the one hand, and the amount of space required by the service on the other. This discrepancy may take two forms. The first occurs when the facility is too small and cannot satisfy the service's spatial needs. The other is when a service is offered in a facility that is too large in terms of the service's needs. Neither of these scenarios is desirable. Too small a facility can affect service quality because space scarcity can prevent the service from developing to its full potential, and can affect working conditions. On the other hand, too large a facility satisfies the service spatial requirements fully, but is not economically efficient, since space is one of the most valuable assets of any organization and having it in excess can be considered as a waste of resources.

Taking into account this situation, the main goal of this thesis is to provide a novel, low-cost and non-expert solution to enhancing space-use in public facilities, and improving conditions for offering a particular service. This solution fills the gap between the facility location problem on the one hand and facility layout, as well as scheduling problems on the other. For that purpose, initially, the coexistence of public services and facilities have been analyzed with regard to the example of the city of Girona. The results of this analysis reveal that space scarcity occurs relatively infrequently, while space excess is uncovered in numerous facilities.

Following this observation, a method for determining space needs has been proposed. This is the first main contribution of this thesis. This method takes into account all service activities in order to determine the amount of space needed at any moment (space demand). The space demand is subsequently compared with the amount of space available in the facility under consideration (space supply) to determine the extent of either space excess, deficiency or adequacy. This exercise was conducted with regard to multiple public facilities in order to provide a situational awareness in terms of space-use within the entire city.

The subsequent part of the thesis concentrates particularly on how to enhance space-use in the case of public facilities. This issue has been approached by repurposing existing facilities and introducing additional services, thereby creating multi-service facilities. However, the services to be combined cannot be chosen randomly, but should be selected according to their mutual compatibility. For this reason, a method for service compatibility analysis has been developed, which is the second key contribution of this thesis. The method takes advantage of feature modelling to describe the different aspects of services quantitatively. Subsequently, the distance between feature values is computed to establish the degree of service coincidence. This allows us to identify bundles of services that could be combined and offered together, and services whose combination should be avoided.

Furthermore, the results of the space-use analysis as well as the service compatibility analysis are visualized in a user-friendly way to facilitate interpretation and to help in decision-making. All these elements constitute the framework for space-use optimization

and arrangement of public services in order to enhance space-use and to decrease the consumption of other, related resources such as energy or water, to make the city environment more sustainable and smarter.

Resum

Els serveis públics constitueixen la interfície específica entre els ciutadans i els diferents organismes de l'administració pública. Aquest únic punt de contacte permet una interacció bilateral. En diferents aspectes, com ara: salut, educació, cultura, etc. un funcionament apropiat és indispensable per al benestar de la societat. Tots els serveis públics requereixen un equipament - l'edifici on poden ser assistits, com ara: hospitals, escoles o museus. Per aquesta raó, els serveis i equipaments públics són dos components integrals del funcionament d'una ciutat i han d'estar ben ajustats. En particular, els equipaments han de proporcionar suficient espai per donar suport a totes les activitats de servei. Cada equipament té un determinat espai que poques vegades canvia durant el cicle de vida de l'edifici. D'altra banda, cada servei té determinats requisits d'espai. No obstant això, aquests requisits són objecte de canvis constants associats amb fluctuacions econòmiques, polítiques, socials i demogràfiques que afecten contínuament al servei.

Aquestes circumstàncies donen com a resultat un desajust entre la quantitat d'espai disponible en l'equipament, d'una banda, i la quantitat d'espai demandat pel servei, de l'altra. Aquesta discrepància pot prendre dues formes. La primera es produeix quan l'equipament és massa petit i no pot satisfer les necessitats espacials del servei. La segona és quan el servei s'ofereix en un equipament molt gran pel que fa a les necessitats del servei. Cap d'aquests escenaris és desitjat. El primer afecta la qualitat del servei perquè l'escassetat d'espai afecta les condicions de treball i evita que el servei desenvolupi tot el seu potencial. El segon, satisfà completament els requisits espacials de servei, però no és econòmicament eficient, ja que l'espai és un dels actius més valuosos de qualsevol organització i el seu excés pot considerar-se com un malbaratament de recursos.

Tenint en compte aquesta situació, l'objectiu principal d'aquesta tesi és proporcionar una solució nova, de baix cost i de fàcil ús per millorar l'eficiència de l'ús de l'espai en els equipaments públics i millorar les condicions de servei. Aquesta solució cobreix la bretxa entre el problema de localització d'equipament (ang.: facility location problem) d'una banda i el disseny interior (ang.: layout problem), així com el problema de planificació de processos (ang.: schedulling problem) per l'altre. Per a això, inicialment s'ha analitzat la coexistència entre els serveis i equipaments públics utilitzant com a exemple la ciutat de Girona. Els resultats d'aquesta anàlisi han revelat que l'escassetat d'espai és relativament poc freqüent, mentre s'ha descobert excés d'espai en nombrosos equipaments.

Seguint aquesta observació, s'ha proposat un mètode per a determinar les necessitats espacials, que és la primera aportació d'aquesta tesi. Aquest mètode té en compte totes les activitats de servei per determinar la quantitat d'espai necessari en qualsevol moment (demanda d'espai). La demanda d'espai es compara posteriorment amb la quantitat d'espai disponible en l'equipament corresponent (oferta d'espai) per esbrinar l'excés d'espai, la deficiència o la conformitat. Aquest exercici realitzat en múltiples equipaments públics proporciona una consciència situacional sobre l'ús de l'espai a escala de ciutat.

La part final de la tesi se centra particularment en com millorar l'ús de l'espai en els equipaments públics. Aquesta qüestió s'ha abordat mitjançant la reutilització dels equipaments existents i la introducció de serveis addicionals creant així els equipaments de serveis múltiples (ang.: multi-service facility). No obstant això, els serveis que es combinen no poden ser elegits de manera aleatòria, sinó que han de ser seleccionats d'acord amb la seva compatibilitat mútua. Per aquesta raó, s'ha desenvolupat un mètode per a l'anàlisi de compatibilitat de serveis, que és la segona aportació clau d'aquesta tesi. Aquest mètode utilitza el modelatge de característiques (ang.: feature modelling) per descriure els serveis quantitativament en diferents aspectes. Posteriorment es calcula la distància entre els valors de les característiques per establir el grau de coincidència entre serveis. Això permet identificar conjunts de serveis que s'han de combinar i oferir junts i serveis que la seva combinació ha de ser evitada.

A més, els resultats de l'anàlisi de l'ús d'espai i de l'anàlisi de compatibilitat de serveis es visualitzen d'una manera intuïtiva per facilitar la interpretació i ajudar en la presa de

decisions. Tots aquests elements constitueixen el marc per a l'optimització de l'ús de l'espai i l'organització dels serveis públics. El marc ha de millorar l'ús d'espai basat en la consciència de la situació i disminuir el consum d'altres recursos relacionats, com l'energia o l'aigua, per fer l'ambient de la ciutat més sostenible.

Resumen

Los servicios públicos constituyen una interfaz específica entre los ciudadanos y diferentes organismos de la administración pública. Este único punto de contacto permite una interacción lateral y su funcionamiento apropiado en diferentes aspectos, tales como: salud, educación, cultura, etc. es indispensable para el bienestar de la sociedad. Todos los servicios públicos requieren un equipamiento - el edificio donde pueden ser ofrecidos, tales como: hospitales, escuelas o museos. Por esa razón, los servicios y equipamientos públicos son dos componentes integrales del funcionamiento de una ciudad y deben estar bien ajustados. En particular, los equipamientos deben proporcionar suficiente espacio para apoyar todas las actividades de servicio. Cada equipamiento tiene un determinado espacio que rara vez cambia durante el ciclo de vida del edificio. Por otro lado, cada servicio tiene determinados requisitos de espacio. Sin embargo, estos requisitos son objeto de cambios constantes asociados con fluctuaciones económicas, políticas, sociales y demográficas que afectan continuamente al servicio.

Estas circunstancias dan como resultado un desajuste entre la cantidad de espacio disponible en el equipamiento, por un lado, y la cantidad de espacio demandado por el servicio, por el otro. Esa discrepancia puede tomar dos formas. La primera se produce cuando el equipamiento es demasiado pequeño y no puede satisfacer las necesidades espaciales del servicio. La segunda es cuando el servicio se ofrece en un equipamiento muy grande en cuanto a las necesidades del servicio. Ninguno de estos escenarios es deseado. El primero afecta la calidad del servicio porque la escasez de espacio afecta las condiciones de trabajo y evita que el servicio desarrolle todo su potencial. El segundo, satisface completamente los requisitos espaciales de servicio, pero no es económicamente

eficiente, ya que el espacio es uno de los activos más valiosos de cualquier organización y su exceso puede considerarse como un desperdicio de recursos.

Teniendo en cuenta esta situación, el objetivo principal de esta tesis es proporcionar una solución novedosa, de bajo costo y no experta para mejorar la eficiencia del uso del espacio en los equipamientos públicos y mejorar las condiciones de servicio. Esta solución cubre la brecha entre el problema de localización de equipamiento (ing.: facility location problem) por un lado y el diseño interior (ing.: layout problem), así como el problema de planificación de procesos (ing.: schedulling problem) por el otro. Para ello, inicialmente se ha analizado la coexistencia entre los servicios y equipamientos públicos utilizando como ejemplo la ciudad de Girona. Los resultados de este análisis revelaron que la escasez de espacio es relativamente poco frecuente, mientras que el exceso de espacio se descubrió en numerosos equipamientos.

Siguiendo esta observación, se ha propuesto un método para determinar las necesidades espaciales, que es el primer aporte principal de esta tesis. Este método tiene en cuenta todas las actividades de servicio para determinar la cantidad de espacio necesario en cualquier momento (demanda de espacio). La demanda de espacio se compara posteriormente con la cantidad de espacio disponible en el equipamiento correspondiente (oferta de espacio) para averiguar el exceso de espacio, la deficiencia o la conformidad. Este ejercicio realizado en múltiples equipamientos públicos proporciona una conciencia situacional sobre el uso del espacio a escala de la ciudad.

La parte final de la tesis se centra particularmente en cómo mejorar el uso del espacio en los equipamientos públicos. Esta cuestión se ha abordado mediante la reutilización de los equipamientos existentes y la introducción de servicios adicionales creando así los equipamientos de servicios múltiples (ing.: multi-service facility). Sin embargo, los servicios que se combinan no pueden ser elegidos de manera aleatoria, sino que deben seleccionarse de acuerdo con su compatibilidad mutua. Por esta razón, se ha desarrollado un método para el análisis de compatibilidad de servicios, que es el segundo aporte clave de esta tesis. Este método utiliza el modelado de características (ing.: feature modelling) para describir los servicios cuantitativamente en diferentes aspectos. Posteriormente se calcula la distancia entre los valores de las características para establecer el grado de

coincidencia entre servicios. Esto permite identificar conjuntos de servicios que deben ser combinados y ofrecidos juntos y servicios cuales combinación debe ser evitada.

Además, los resultados del análisis del uso de espacio y del análisis de compatibilidad de servicios se visualizan de una manera intuitiva para facilitar la interpretación y ayudar en la toma de decisiones. Todos estos elementos constituyen el marco para la optimización del uso del espacio y la organización de los servicios públicos. El marco debe mejorar el uso de espacio basado en la conciencia de la situación y disminuir el consumo de otros recursos relacionados, como la energía o el agua, para hacer el ambiente de la ciudad más sostenible.

Introduction

Research context

Public services are a key responsibility of (local) government. They are collaborative activities carried out by public administrations to fulfill the requirements of citizens and to improve their quality of life (Hourie, Malul, & Bar-El, 2015). It is also a peculiar form of human interaction connecting citizens with different public administration bodies (Taher et al., 2010). This interaction takes place in several areas such as education, healthcare or culture, which are the most fundamental aspects of city life and are provided regardless of the geographical or political context. Yet, other types of services are more arbitrary. Hence, there is no one, universal and coherent catalogue of public services. Different researchers or institutions classify them in distinctive ways. For instance, Burchardt (1997) determines five service categories: Education, Health, Housing, Social security and Personal social services. Further, Marsal-Llacuna, Leung & Ren (2011) enumerate nine categories of public services: Education, Sports, Health, Social assistance, Culture, Commercial services, Religious services, Transportation, Administration and Protection. Alternatively, the United Nations Statistics Division (2016) specifies the main functions of governments in terms of the following areas: General public services, Defense, Public order and safety, Economic affairs, Environmental protection, Housing and community amenities, Health, Recreation, Culture and religion, Education and Social protection. It can be noted that, regardless the approach, without taking into account the different number of elements or their names, each classification includes all necessary

aspects for social wellbeing, and it is possible to establish correlations between the components of these taxonomies.

Public services need a place to be delivered, a building called a public facility. This built environment should support the provision of the goals of the service offered within, in an effective, efficient and equitable way (Kwok, & Warren, 2005). Therefore, public facility can be defined as an infrastructure that supports people in their activities in order to achieve their goals (McGregor, & Then, 1999). Similarly, with regard to services, there are various classifications of public facilities. For instance, Austin (2005) defines five categories of public buildings: Educational facilities, Health facilities, Recreational facilities, Cultural facilities and Administrative facilities. The Government of Catalonia specifies ten categories of public facilities: Educational facilities, Health facilities, Administrative facilities, Cultural facilities, Social facilities, Religious facilities, Sport facilities, Funeral facilities, Transportation facilities and Security and protection facilities (Montalbo, 2012). Furthermore, the City of Seville specifies eight types of facility: Educational, Sport, Health, Social Welfare, Socio-cultural, Administration, Socio-economic and Civic services (Sevilla, 2006).

It is evident that the classifications of public services are very similar to the classifications of public facilities. This is because normally a service is strongly associated with a facility. This correlation is depicted in Figure 1.

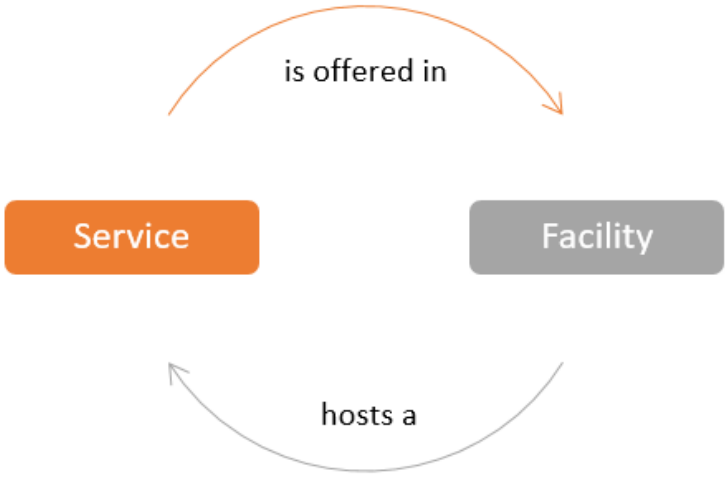

Figure 1. Relationship between service and facility.

The most common type of correlation between service and facility is a one-to-one relationship in which a service is offered in one facility, and the facility hosts only one service. In such a case the service is usually identified with the facility, e.g. the service of education and a school facility are commonly referred to as a school. Another type of association is a one-to-many relationship which occurs when more than one service is offered in a facility which is entitled a multi-service facility (MSF). For example, we have such a situation when a library, education and cultural service are offered together under one roof.

This association between service and facility can be also transferred to a lower level which defines a service as a collection of activities and a facility as a collection of spaces. Space can be defined as a physical entity that accommodates a user activity (Kim, 2013). Therefore, for a facility to be cost-effective and efficient it should provide an appropriate amount of space according to the number of people and type of activities that are carried out. This interrelationship is depicted in Figure 2.

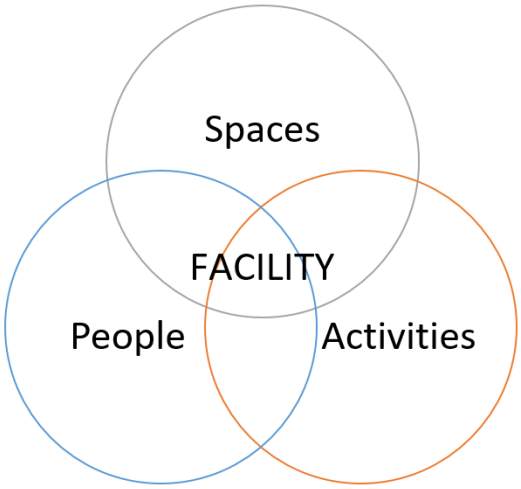

Figure 2. Interrelation of people, space and activities making up a facility (adapted from: McGregor & Then, 1999).

In this amalgam of people, spaces and activities encompassed by a facility, people are the reason for it existence and the most important component. Activities exist to fulfill particular goals, and space should support these activities. For this reason, space must be constantly adjusted according to the people's needs to make their activities fit into the building structure (Wiggins, 2010). This task, although it seems to be obvious, is not easy

to achieve in the real world. This is because public services (intangible factor) are very sensitive to environmental, economic and, most of all, social change. Consequently, they experience constant modifications. However, public facilities (physical factor), as a built environment, are not very responsive to such a variation. In consequence, the demand for space changes over time, whereas the amount of space available in a facility remains constant. Thus it is not uncommon that service spatial requirements are not aligned with the amount of space that is available.

According to the results of a survey and personal interviews conducted in June 2014 with 30 directors of public services in Girona, the two most commonly reported factors that impact on the demand for public services were the recent economic crisis and the transformation of society's age structure.

The impact of the crisis did not change the demand for educational, health care, administration and protection services. However, cultural, commercial and sport services experienced a decline, and the number of users and activities decreased. In consequence, their space requirements were lower than previously. In contrast, social services, especially those related to employment, experienced a strong increase in the number of users. This resulted in increase of the number of activities for which more space was needed.

The other factor - transformation of the society's age structure - is mostly influenced by a significant decrease in the birth rate (Population Division, 2014). This phenomenon can be exemplified in the case of a school facility designed and constructed thirty years ago to accommodate 500 students. Owing to the fall in the birth rate, the number of students has decreased to approximately 350. This leads to the following observation: if the same amount of space is used for teaching fewer students, it means that probably the service is occupying more room than is needed. If this is true, then perhaps the excess space can be used for the provision of other compatible services.

These findings indicate a need for solutions dealing with continuing space adjustment between public services and facilities. For this reason, the context of this thesis is at the cross section of facility management (FM) as well as service science (SS), as depicted in Figure 3.

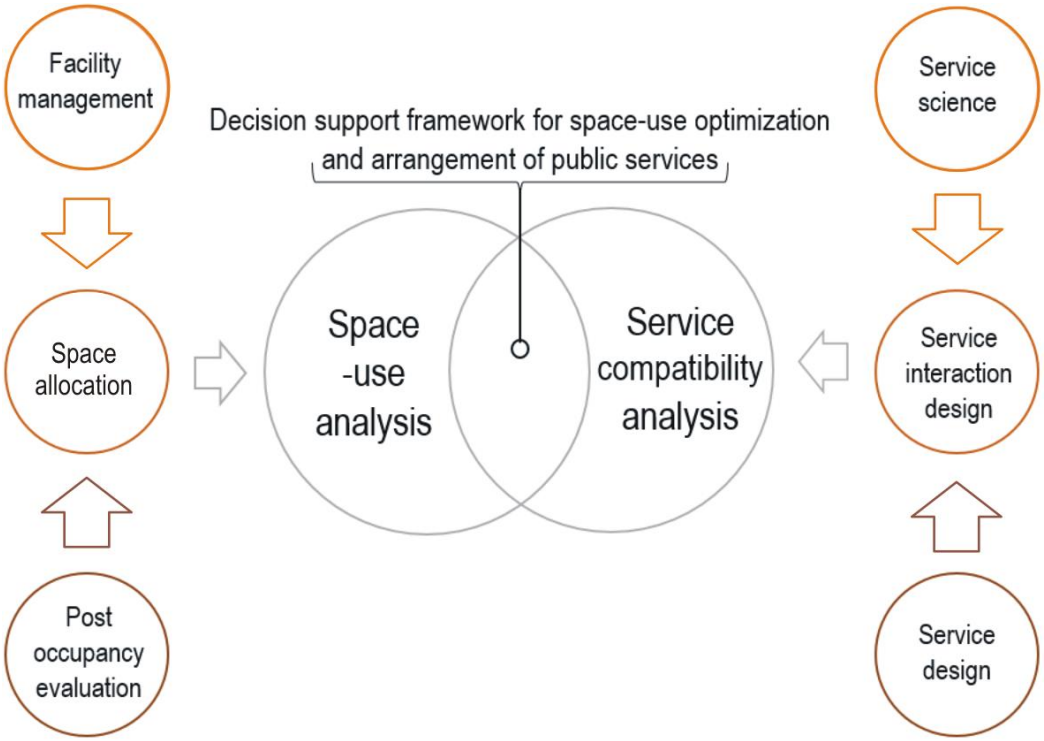

Figure 3. Context of the thesis at the cross section of facility management and service science.

The framework combines a physical aspect (building) with an intangible one (service). Thus, one aspect is based on FM which is an extensive subject encompassing the full scope of operations related to a building during its life cycle. The International Facility Management Association (IFMA, n.d.) defines FM as an amalgam of multiple disciplines to ensure the functionality of the built environment by integrating people, place, process and technology. The framework does not involve the process of design and the construction of new buildings, but focuses on the existing ones, which is the domain of post- occupancy evaluation (POE). POE analyses buildings in various aspects after they have been built and occupied for some time (Preiser, Rabinowitz, & White, 1988). The central issue draws from both FM and POE, but is particularly concerned with allocating appropriate amounts of space for public services. Thus, space allocation seeks how space can efficiently accommodate an organization's needs and determines if space reduction or expansion is required (Archibus, n. d.).

On the other hand, the framework takes advantage of SS which applies scientific understanding to the design and improvement of services (Maglio, & Spohrer, 2007). According to Mager (2009), service design (SD) "…aims to ensure service interfaces areuseful, usable and desirable from the client's point of view and effective, efficient and distinctive from the supplier's point of view". Regarding the service side, the framework concentrates on combining public services in an advantageous way to support positive interaction. To analyze how services are related to one another, the concept of interaction design (IxD) is used, which strives to create meaningful relationships between people, products and services (IxDA, n. d.).

Motivation

The European Commission states that the system of public services provision needs to be more effective, and that innovative solutions for creating public value are necessary (Public Services Unit, 2013). Taking into account a changing environment, the number of public facilities and the variety of services offered on the scale of a city is a big challenge for the public sector in terms of how to manage this set of services and buildings (Zhang, & Gao, 2010). A lack of appropriate management results in overused and underused buildings. Both of these situations should be avoided. Overused facilities impact negatively on working conditions, and decreases service quality, thereby preventing its development. On the other hand, underused facilities waste space, which is an expensive asset. It is not only because space is costly to buy and maintain, but also because space entails the consumption of other valuable resources such as energy or water. Therefore, the proper use of space is a determining factor with regard to prosperous facilities, and ensuring an adequate amount of space is crucial for service quality on the one hand, and for economic efficiency on the other.

Nevertheless, determining space needs in any organization, and in public sector organizations in particular, is not an easy task. This is because people's needs are unlimited by nature, and few departments would voluntarily give up space (FMLink, 2016). Even if there is a space excess, a typical department would say that is unable to

relinquish any of it (Kimmel, n.d.). For this reason, other, more objective methods for determining space needs, have to be applied.

There are many techniques for measuring building utilization. The most effective ones take advantage of building information modelling (BIM) systems, allowing the determination of space needs based on peoples' activity. For this purpose, radio frequency identification (RFID), sensors and the tracking of mobile devices are used. These solutions, however effective, are expensive to apply and maintain, requiring both economic and qualified human resources. Nevertheless, a significant number of public facilities, the initial investment and costs of upkeep make this solution unfeasible for many organizations. This reveals the need for a more objective, low cost and non-expert method to determine actual space needs.

Another issue concerning more efficient space-use is related to how to re-use the released space more efficiently. This is because detecting even small areas provides a real possibility of optimization. According to Cowan (1963) most human activities take place within an area of 20m^2, but even areas as small as 2.5 m^2 have been found sufficient for various activities. Thus, in this thesis, a more efficient space-use has been suggested by repurposing facilities and introducing additional services to combine with already existing ones. According to Lee & Lee (2014) a combination of services in most cases is based on public administration organizational charts, without taking into account functional relationships between services. This wastes the opportunity of adding value by combining services related to one another. Services should not be combined randomly but rather purposefully, in the way that enhances the performance of the totality. For this reason, a method for the advantageous and meaningful combination of services is necessary.

Objectives

The main objective of this thesis is to develop a framework for a more efficient space-use in multiple, public facilities of different kinds.

This general objective is composed by two specific contributions:

1. **The development of an activity-centered method for determining utilization in a range of public facilities.**
   This method should take into account a variety of different types of activities to determine space needs, and compare them with the amount of space that is available. In addition, the results of the space-use analysis performed with regard to multiple public facilities should provide a situational awareness, and be represented in a user-friendly manner to facilitate interpretation and help in decision-making.
2. **The development of a quantitative method for determining service compatibility.**
   This method should allow for a more efficient space-use in public facilities. The results of Objective 1 should identify facilities with excess space. This space may be used for introducing additional service or services that are compatible with each other. Such an advantageous combination of services should lead to the repurposing of traditional single-service facilities and converting them into multi-service facilities.

Chapter 1

Decision support framework for space-use efficiency and arrangement of public services

Rusek, R., Marsal-Llacuna, M. L. & Colomer-Llinàs, J. (2017). Decision support framework for space-use efficiency and arrangement of public services. *Submitted to: Indoor and Built Environment* (IF: 0.943, Q3, rank: 33/61 in construction & building technology).

Abstract

This article focuses on the issue of spatial adjustment between public facilities and services. It highlights the importance of sustainable space-use and the beneficial arrangement of public services, and discusses the main reasons for their inefficient provision: different administration bodies responsible for facilities planning and service programming; lack of citizens' participation; lack of entrepreneurship in the public sector and lack of resilience in the face of a changing environment. Subsequently, a solution aimed at mitigating these negative effects - a conceptual framework underpinning a planning and evaluation tool for decision support - is presented and discussed in terms of particular examples. The framework consists of two decisive elements: space-use analysis and service compatibility analysis. The first aims to determine the degree of space utilization in a range of public buildings, while the latter reports on how services are related to each other in terms of their compatibility. The article concludes with the benefits of the framework for different groups of city stakeholders (city council, citizens, NGOs and private companies) under the Public-Private-People Partnership paradigm.

Keywords

Public facilities; public services; space efficiency; space-use analysis; multi-service facility

Submitted paper. Embargoed until publication

Chapter 2

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

Rusek, R. & Colomer-Llinàs, J. (2017). A comparison study on space-use analysis techniques and proposal of a novel method for determining space needs in public facilities. Submitted to: Building Research & Information (IF: 2.196, Q1, rank: 10/61 in construction & building technology).

Abstract

This paper deals with the issue of 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 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. The paper also clarifies the need for switching perspective from building/room centered to service/activity centered. 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. This method has been described in details, tested and exemplified.

Keywords

Space-use, space needs assessment, space efficiency, public facilities optimization

Submitted paper. Embargoed until publication

Chapter 3

Compatibility of municipal services based on service similarity

Rusek, R., Marsal-Llacuna, M. L., Torrent-Fontbona, F., & Colomer-Llinàs, J. (2016). Compatibility of municipal services based on service similarity. *Cities 59* (2016): 40-47 (IF: 2.051, Q1, rank: 5/39 in urban studies).

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Compatibility of municipal services based on service similarity

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ABSTRACT

The aim of this article is to propose and examine a quantitative method of determining the degree of compatibility between municipal services. Provision of services and facilities maintenance are usually two biggest expenditures of local governments. Traditionally, facilities host only one service, whereas the challenge and opportunity lies in combining various, compatible services and offering them together under one roof. Such a combination decreases municipal expenditure and has a strong positive impact on the general service quality. For this purpose, we take advantage of the City-block distance formula to calculate the degree of compatibility between municipal services. The method is examined and discussed on a sample of 30 real municipal services. This allows us to find possible combinations of strongly compatible services that should be offered together in Multi-Service Facilities and, at the same time, avoid an unwanted combination of services that are incompatible.

1. Introduction

The delivery of public services and facilities maintenance is a critical function of local governments (Zolnik, Minde, Gupta, & Turner, 2010). It is a key aspect of city management due to its direct influence on city competitiveness and citizens' quality of life (Lee & Lee, 2014). Consequently, it is also usually the most important expenditure of public administration due to its social function. Despite this, recent studies suggest that public services and facilities are in many cases poorly managed (Gonzalez, Llopis, & Gasco, 2013; Kwok & Warren, 2005). This is because for many years innovation research has been focused on the industrial sector, whereas public services have received little attention (Gonzalez et al., 2013). In addition Tan, Koray, and Baum (2008) report that all urban activities are unsustainable by definition because they consume resources. To that end, Cosgrave, Tryfonas, and Crick (2014) suggest that the solution to this problem should be in seeking to improve the quality of services at lower resource costs. Therefore, we theorize that in an economic downturn a reduction of resources used for the provision of public services should be the fundamental element of the municipal optimization strategy.

van den Dobbelsteen and de Wilde (2004) remark that optimization should start from a reduction in the demand for space. At the city level significant savings may be achieved through a more efficient adjustment of the surfaces used for public services provision. According to Neirotti, De Marco, Cagliano, Mangano, and Scorrano (2014) Information and Communication Technologies play an important role in this issue. Specifically, the emergent practice of service virtualization that forms a part of e-government initiatives contributes to, inter alia, efficient management and cost reduction (World Bank, 2015). Services available online enable citizens to communicate and interact with city representatives without the need of visiting the appropriate facility personally. This, in a direct way, releases the space occupied especially by services, where citizen attention zones are significant. Moreover, virtual services decrease the number of workplaces due to automatization processes. However, in spite of this not all services can be virtualized. Sport, social or cultural are types of services that require in person participation. Others can be virtualized only partially, for example a basic health care consultation can be provided online; more specific treatment requires a specialized facility. Furthermore, even in so-called highly developed countries the problem of a Digital Divide exists, and prevents services from being fully virtualized. For these reasons service virtualization, however advantageous, does not solve the issue of conserving physical space completely, other simultaneous actions are necessary.

Marsal-Llacuna, Leung, and Ren (2011) suggest that Multi-Service Facilities (MSF) can be a response to this problem since they reduce the amount of urban land necessary for public services provision and decrease their cost. Consequently, we are convinced that the essential step for public resource saving is a rewarding combination of compatible services in the facility building. Such a solution permits more than one activity to take place at the same time and location (Batty, Besussi, Maat, & Harts, 2004). Furthermore, efficient use of already available resources makes this approach economically sustainable

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0264-2751/

because it increases the occupation rate implying that more people use the same area, or the same number of users uses a smaller area (van den Dobbelsteen & de Wilde, 2004).

These considerations lead us to formulate the following hypothesis: Is it possible to establish the degree of compatibility between public services for their advantageous combination in MSF?

1.1. Municipal services

Public services are essential for a city to properly function. In general terms they are services provided by administrations of different levels (state, regional, municipal) in exchange for taxes. Thacker (2009) defines more precisely that public service is a piece of work performed by the public administration on behalf of the citizens. A general term of public service is sometimes substituted by others, corresponding to administrations of different levels: local, municipal or urban service. Here we are exclusively focused on services that are a municipal responsibility. Moreover, we consider only these services that require a physical space to be offered - a facility.

1.2. Facilities

A public facility in this frame of reference is a building intended for the provision of public services. Bennett and Iossa (2006) define two stages of the public facilities development process: building and management. Building a new facility is an easier way to respond to current social needs because the number of constraints is relatively low. Such an approach allows services to be very carefully planned and eventually obtain a good quality results. However, it is also expensive and difficult to execute, especially in an economic downturn. Hence, we mainly focus on the facility management stage and postulate that the challenge is to intentionally repurpose existing facilities by retrofitting them with other, compatible services.

1.3. Service-facility relationship

Service and facility are two concepts that are often confused. It is probably a consequence of mental shortcuts commonly used in everyday language. For instance, it is common to hear people speaking of a school. In fact, a school is a mental shortcut encompassing two concepts: a building (container) and a service of education (content) (Marsal-Llacuna et al., 2011). It is of crucial importance to distinguish these two components, as summarized in Table 1.

To sum it up: a service is an intangible process or activity that constitutes the content of a physical container – a building. A service is primordial, while a facility is secondary – it exists only to provide appropriate conditions for service offering.

Based on a research encompassing scientific papers, organization charts and different city administrations we discovered three types of relationships between services and facilities. The most common is a one-to-one relationship where a service is offered in one facility and a facility hosts only one service. In such cases a service is usually identified with a facility and mental shortcuts are created, e.g. a school refers to the building as well as the service of education. Another case occurs when a service requires more than one facility, e.g. a waste management service takes place in a waste treatment facility and recycling plant. The last variant takes place when more than one service is offered in one facility (MSF), for example, social youth service, multimedia library service and gym service are offered together in a community centre facility.

Table 1
Comparison of two concepts: a service and a facility.

Service	Facility
• Activity/process	• Building
• Content	• Container
• Intangible	• Physical
• Primordial	• Secondary

1.4. Compatibility

The Oxford Dictionary provides a general definition of compatibility, which is: “a state in which two things are able to exist or occur together without problems or conflict” (Compatibility, 2015). The fundamental question that emerges is, when are some “things” compatible and when are they not? Depending on the discipline, the approach for compatibility differs. In some cases compatibility can be explicitly verified; for instance, blood compatibility, compatibility of substances in chemistry or compatibility of web services. However, there are also objects whose compatibility cannot be clearly measured. Such a situation occurs in social science where compatibility is usually identified with similarity. We take the same approach for the issue of service compatibility and consider that the more similar the services, the more compatible they are. In this context compatibility of services is crucial because the value is generated only when compatible elements are consumed together, otherwise the utility of the totality is greatly reduced (Desruelle, Gaudet, & Richelle, 1996).

2. Material and methods

In this section we present a method for determining the degree of service compatibility. However, before going into detail, it is important to discuss circumstances that make some services more amenable for compatibility assessment than others.

First of all, services are provided by various administrative bodies within distinct governmental levels. In Catalonia, Spain, public services are programmed by different entities at the State, Autonomous community, Province and Municipal level. Unfortunately, there is little cooperation between these bodies in terms of public services and facilities. Consequently, a facility building is usually a property of the entity that delivers the service. This imposes a separate approach for services and facilities provided by each governmental level, and dramatically reduces possible benefits resulting from shared use of space. Due to these circumstances theoretically compatible services that are administered by different authorities, in the real world, are not likely to be combined. For this reason, to make this research more realistic, we restrict application of the method to services that are exclusively a municipal responsibility.

Another limitation concerns sensitive services such as religious, safety or funeral services. These are services which, due to their character, should not be combined with others for safety or ethical purposes. For this reason all sensitive services have been excluded from our considerations.

Having applied the abovementioned restrictions, in the following sections we present the method of service description and a calculation of compatibility.

2.1. Service features

A profound research on the system of municipal services provision has been conducted to find a universal way of service description and comparison. As a result, we propose a set of seven features that in our opinion characterize services in the best way and make them comparable. The features are as follows: Affiliation, Delivery, Nature, Presence, Scope, Stakeholder and User. Each of these features consists of attributes. Every attribute has a percentage value. The value can be either binary (in this case 0% or 100% because for legibility purposes, we present the results on a percentage scale) or relative (each attribute may have a different value from 0% to 100%). It is important to stress that these values are compositional data - they always have to sum 1 (in this

Table 2
A summary of service features with their attributes.

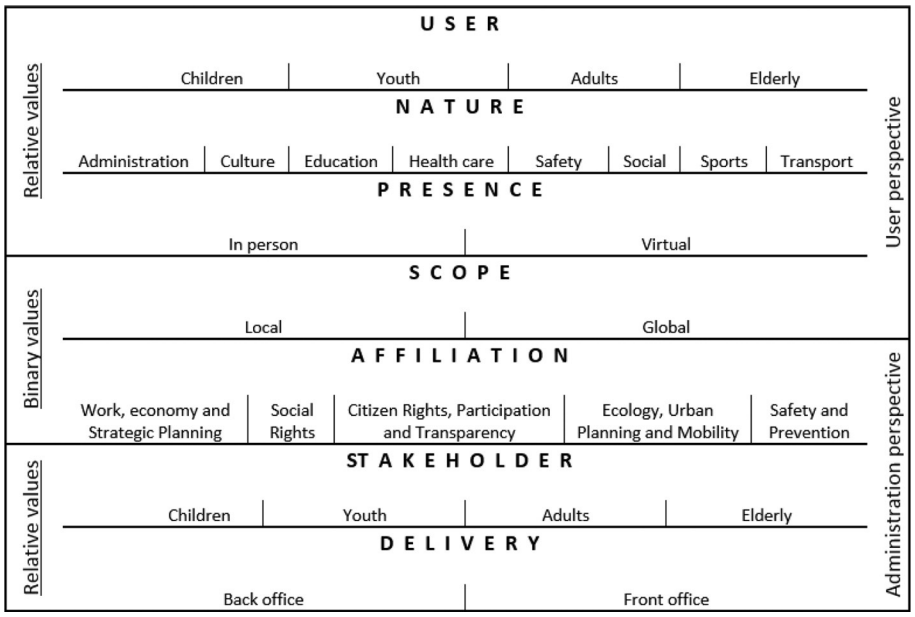

Illustration 1. Spatial distribution of 30 sample services. The numbers marked in orange with an arrow indicate services that are offered in the same facility. Services 03, 04, 12, 28, 29, and 30 are hosted in the Town Hall.
Source: Unitat Municipal d'Anàlisi del Territori, Girona.

Table 3
Quantitative description of municipal services.

Service name		"l'Olivera" Nursery School Service	Municipal Service of Territorial Analysis	Migdia Primary School Service
Feature	Attribute	Value		
User	Children	100%	10%	100%
	Youth	0%	35%	0%
	Adults	0%	50%	0%
	Elderly	0%	5%	0%
Nature	Administration	0%	50%	0%
	Culture	0%	20%	10%
	Education	5%	30%	70%
	Health care	0%	0%	0%
	Safety	0%	0%	0%
	Social	95%	0%	10%
	Sports	0%	0%	10%
	Transport	0%	0%	0%
Presence	In person	100%	20%	100%
	Virtual	0%	80%	0%
Scope	Local	100%	0%	100%
	Global	0%	100%	0%
Affiliation	Office of the Mayor	0%	0%	0%
	Department of Citizens	100%	0%	100%
	Department of Urban Planning	0%	100%	0%
	Department of Finance and Sustainability	0%	0%	0%
	Department of Promotion and Employment	0%	0%	0%
	Department of Safety, Mobility and Public Space	0%	0%	0%
	Department of Social Services	0%	0%	0%
Stakeholder	Children	60%	5%	60%
	Youth	10%	40%	15%
	Adults	25%	50%	20%
	Elderly	5%	5%	5%
Delivery	Back office	10%	90%	10%
	Front office	90%	10%	90%

Table 4
Degree of compatibility for every feature between the "l'Olivera" Nursery School Service and 29 other sample services. All values in %.

		Municipal Service of Territorial Analysis	Municipal Habitat Service	Council Tax Service	Service of Citizen Attention	Service of City Historical Archive	Service of Image Research and Dissemination	Tourist Office Service	Municipal Employment Service	Library Service "Antònia Adroher"	School Library Service "Montfollet"	Public Library Service "Carles Rahola"	Catalan Language Promotion Service	Service of City History Museum
"l'Olivera" Nursery School Service	Affiliation	0	0	0	100	0	0	0	0	0	0	0	0	0
	Delivery	20	30	40	90	90	90	100	70	90	100	100	10	90
	Nature	5	50	0	5	5	5	15	35	15	25	10	5	5
	Presence	20	90	60	90	95	70	60	95	100	95	95	100	90
	Scope	0	0	0	0	0	0	0	0	100	100	0	0	0
	Stakeholder	45	50	40	45	45	50	45	35	45	90	45	45	65
	User	10	0	0	5	5	20	10	0	10	90	10	25	30

case 100%) (Pawlowsky-Glahn & Egozcue, 2006). In Sections 2.1.1–2.1.7 all proposed features and attributes are described in detail.

2.1.1. Affiliation

Affiliation refers to the administration department responsible for providing a particular service. Thus, typical attributes of this feature are names of administration units e.g.: Recreation, Planning, and Public works. However, it is important to realize that administration departments are context-dependent. In consequence, the names and number of attributes can vary from one city to another, due to the different organization schemes. The value of attribute Affiliation is binary, because a particular service is affiliated to one, and only one, city department.

2.1.2. Delivery

The delivery feature has two relative attributes: back office and front office. Back office services are those that users do not interact with directly, for example general administration services. On the other hand, front office services are those where direct interaction with users takes place. They are open to the public, and citizen attention is an important part of the service. These are usually cultural, social or educational services.

2.1.3. Nature

Nature reflects how a service is seen by its users. It is in contrast to the Affiliation feature, which represents the administration perspective. For instance, a primary school service is affiliated to the Department of Education. Thus, it would be considered exclusively as an educational service by the administration. However, users may perceive it as a compilation of different domains such as social, culture, education, etc., rather than a single one. The Nature feature therefore consists of eight relative attributes: administration, culture, education, health care, safety, social, sports and transport.

2.1.4. Presence

The Presence feature refers to the way that the service is delivered to its users. We distinguish two attributes in this feature: in person and virtual. A traditional approach requires the physical presence of the user to deliver the service (in person). For example, in the case of a library service, a user has to visit the library facility to pick up and return a book. Nonetheless, recently, we can observe the process of services virtualization. Virtual services do not require a citizen's physical presence and can be, wholly or partially, delivered online. In person and virtual attributes are not mutually exclusive and therefore are relative: a service can be considered as in person in x% and virtual in y%, respective to the number of users choosing each mode of access.

2.1.5. Scope

The scope feature refers to the distribution of the service across the city area. It has two binary attributes: a service can be either local or global. Global services are those that serve the whole city. There is only one instance of a global service in the city, usually located in a well accessible place in the city centre. Local services, on the other hand, are numerous. They are designed to serve local communities and are distributed across the city area, e.g. a district library.

2.1.6. Stakeholder

The Stakeholder feature specifies all persons who have an interest in a service and somehow participate in it. It is not limited to the service users but encompasses all groups of interest, such as: service staff members and parents who accompany their children to school. This feature differentiates groups of stakeholders according to their age: children, youth, adults and the elderly. We use the following classification: children: 0–18 years; youth: 18–30; adults: 30–75; elderly: 75+, although any other can be used if appropriate. The Stakeholder feature value is considered to be relative, because usually, representatives of various age groups are involved in a service.

2.1.7. User

The User feature corresponds to the stakeholder one with the difference that it reflects the end-user perspective, while the stakeholder reflects the administration one. It refers exclusively to a person who directly interacts with a municipal service. Despite these differences, a user feature has the same set of relative attributes: children, youth, adults and the elderly.

All of the abovementioned features, together with their attributes, are summarized in Table 2.

2.2. Service compatibility

To establish the degree of compatibility, it is necessary to describe every service in a quantitative way. The service description is carried out by filling in the attributes values for every feature. This task has to be done by either a service director or another person with a profound knowledge about the service and its context. Next, the services are organized in pairs. Service comparison comes down to the calculation of the distance between values of their attributes. For that purpose we take advantage of the City-block distance that represents a distance between two points as a sum of the absolute differences of their coordinates (Panigrahi, 2014). The general City-block distance formula is presented below:

$$d = \sum_{i=1}^{n} |xi - yi|$$

However, for the purpose of service comparison it has to be normalized and takes the following form:

$$c(S1, S2) = 100\% - \left(\frac{1}{2}\sum_{i=1}^{n} |S1i - S2i|\right)$$

where:

c = compatibility
S1 = service 1

Table 4 (*continued*)
Degree of compatibility for every feature between the "l'Olivera" Nursery School Service and 29 other sample services. All values in %.

Civic Center Service "Sant Narcís"	Municipal Market Service	Youth Center Service "Els Quimics"	"La Caseta" Educational Service	Service of Municipal Music School	Service of Adult Education	"Migdia" Primary School Service	"Font de l'Abella" Service of Special Education	Service of Municipal School of Art	District Swimming Pool Service	District Sports Pavilion Service	Youth Health Service	"La Sopa" Homeless Shelter Service	Municipal Service Council of LGBT	Municipal Service Council for the Elderly	Service of Communication, Documentation and Marketing
0	0	0	100	100	100	100	100	100	100	100	0	0	0	0	0
100	100	100	100	100	95	100	100	100	90	90	100	100	30	20	10
65	10	35	25	5	15	15	15	5	15	15	35	90	25	35	0
100	100	100	100	100	95	100	100	100	100	100	100	100	90	100	40
100	0	0	0	0	0	100	0	0	100	100	0	0	0	0	0
45	45	85	75	85	40	95	85	70	60	55	65	40	40	40	45
10	5	60	50	60	0	100	100	40	20	20	40	0	0	0	25

$S2$ = service 2
n = number of attributes.

3. Results

In this section we illustrate the method described above on a pilot project that has been conducted on 30 municipal services in the city of Girona, Spain. The sample contains a variety of services of different characteristics to replicate the diversity of the city environment. The complete list of the selected services is as follows:

1. Municipal Service of Territorial Analysis
2. Municipal Habitat Service
3. Council Tax Service
4. Service of Citizen Attention
5. Service of City Historical Archive
6. Service of Image Research and Dissemination
7. Tourist Office Service
8. Municipal Employment Service
9. Library Service "Antònia Adroher"
10. School Library Service "Montfollet"
11. Public Library Service "Carles Rahola"
12. Catalan Language Promotion Service
13. Service of City History Museum
14. Civic Centre Service "Sant Narcís"
15. Municipal Market Service
16. Youth Centre Service "Els Quimics"
17. "La Caseta" Educational Service
18. Service of Municipal Music School
19. "l'Olivera" Nursery School Service
20. Service of Adult Education
21. Migdia Primary School Service
22. "Font de l'Abella" Service of Special Education
23. Service of Municipal School of Art
24. Santa Eugènia - Can Gibert del Pla District Swimming Pool Service
25. Santa Eugènia-Montfalgars District Sports Pavilion Service
26. Youth Health Service
27. "La Sopa" Homeless Shelter Service
28. Municipal Service Council of LGBT
29. Municipal Service Council for the Elderly
30. Service of Communication, Documentation and Marketing

Additionally, the distribution of all the abovementioned services over the city area was marked in Illustration 1.

Each service from the 30 selected has been described by filling in values of attributes for every feature. The result is presented in Table 3. Due to the volume limit, we present a description of only 3 out of all, 30 services.

Next, all 30 services were organized in pairs based on the all-play-all rule. Applying the formula $\frac{n}{2}(n-1)$ for $n = 30, 435$ pairs of services were obtained. Later, the normalized formula of the City-block distance was applied to calculate the service compatibility for every feature. To depict this calculus, let us consider the user feature of the "l'Olivera" Nursery School Service and the Municipal Service of Territorial Analysis. We take the values of attributes from Table 3 and substitute them into the normalized City-block formula as follows:

$$c(S1,S2) = 100\% - \left(\frac{1}{2}|100\% - 10\%| + |0\% - 35\%| + |0\% - 50\%| + |0\% - 5\%|\right)$$
$$= 100\% - \left(\frac{1}{2}(90\% + 35\% + 50\% + 5\%)\right) = 100\% - \frac{180\%}{2} = 10\%$$

It turned out that in this case the compatibility degree is equal to 10% (a relatively low value). Subsequently, we calculate the compatibility of other features in the same way. The results obtained for all features provide an overview of compatibility between services.

Table 4 presents a result of a compatibility calculus for every feature between the "l'Olivera" Nursery School Service and 29 other sample services.

Next we present the results from Table 4 in graphical form on radar charts that visualize the degree of compatibility for each feature clearly. Figs. 1 and 2 illustrate two extreme cases showing respectively high (Fig. 1), and low compatibility degree (Fig. 2).

The features on the graphs are organized according to their values in descending clockwise order for the sake of legibility. Such a graphical representation shows a clear image of the areas in which services coincide and where they differ, helping to interpret the results. The plot in Fig. 1 covers almost the entire chart area reflecting high compatibility in every feature except the nature one, where the compatibility is equal to 15%. This is because the Nursery School service is mostly considered as social, whilst the Primary School service is considered as educational (see Table 3).

Fig. 2 depicts an example of very low general compatibility, reaching the highest value of 45% in the Stakeholder feature. It is also clear that the plot covers only a small part of the entire chart showing that these two services have little in common.

Radar charts also play an important role in obtaining the total compatibility result expressed as the ratio of the area of two polygons: a regular heptagon of the edge ≈ 86,794 (B, Fig. 1) and the polygon created by connecting values of every feature (A, Fig. 1). Total compatibility values for all 30 services are presented in Table 5.

Table 5 presents the compatibility matrix that shows a total compatibility value between each pair of services. It shows that the most compatible are Santa Eugènia - Can Gibert del Pla District Swimming Pool and Santa Eugènia-Montfalgars District Sports Pavilion Service – 87%, whilst the least compatible are "l'Olivera" Nursery School Service and Municipal Service of Territorial Analysis – 2%.

Based on this matrix, we grouped the results into four sets: 1) Services with a result in the range between 100% and 75% are considered to be strongly compatible; 2) those in the range from 75% to 50% are of acceptable compatibility; 3) services with a result from 50% to 25% are of poor compatibility; and 4) services with a result in the range between 25% to 0% are considered to be incompatible. Next, we analysed the compatibility matrix, searching especially for groups of more than two services in every set. The results are as follows:

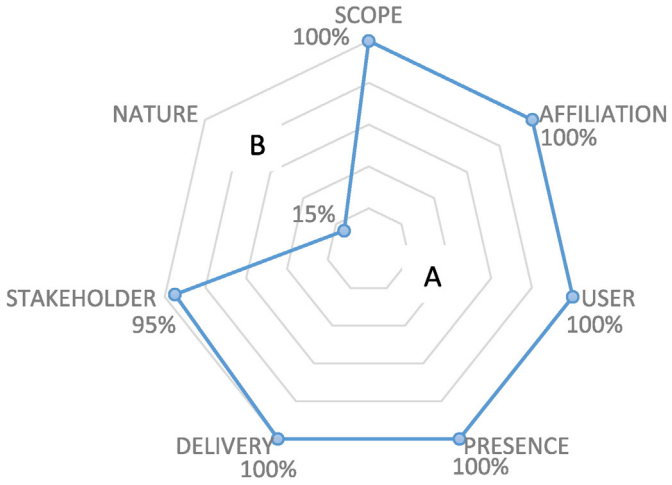

Fig. 1. Graphical representation of compatibility between the "l'Olivera" Nursery School Service and "Migdia" Primary School Service.

In the set of strongly compatible services we discovered two groups of four services:

- Tourist Office Service; Service of City Historical Archive; Service of Image Research and Dissemination and Public Library Service "Carles Rahola,
- Service of City History Museum; Service of City Historical Archive; Service of Image Research and Dissemination and Public Library Service "Carles Rahola,

one group of three services:

- "La Caseta" Educational Service; Service of Municipal Music School and Service of Municipal School of Art,

and 16 other pairs of strongly compatible services.

In the set of acceptable compatibility we discovered one group of three services:

- Santa Eugènia-Montfalgars District Sports Pavilion Service; "l'Olivera" Nursery School Service and "Migdia" Primary School Service,

as well as 57 other pairs of services.

In the set of poor compatibility we discovered 260 pairs of services but not larger groups. Finally, in the last set of services considered to be incompatible we discovered one group of three:

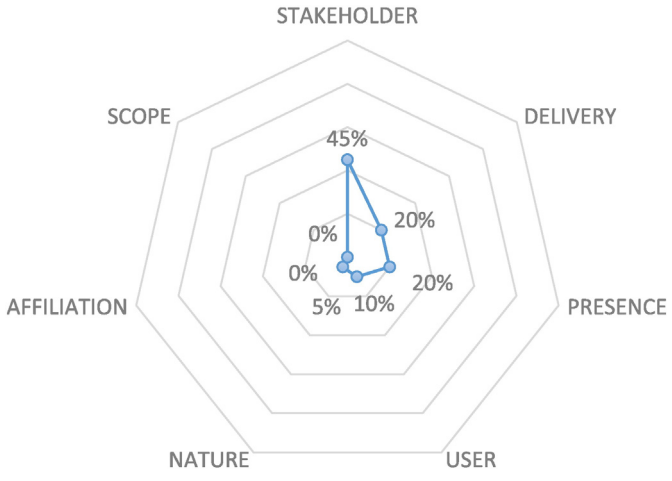

Fig. 2. Graphical representation of compatibility between the "l'Olivera" Nursery School Service and Municipal Service of Territorial Analysis.

- Service of City History Museum; "l'Olivera" Nursery School Service and Municipal Service Council for the Elderly,

as well as 102 other pairs of services.

Additionally, we used the compatibility assessment method to evaluate the services already offered under one roof. In Illustration 1 we can see two cases of MSF. The first case is formed by the Service of City Historical Archive (05) and the Service of Image Research and Dissemination (06). Their compatibility is equal to 81%. We can therefore consider this to be an example of a successful combination of strongly compatible services.

The other case is formed by six services that are offered in the Town Hall building: Council Tax Service (03), Service of Citizen Attention (04), Catalan Language Promotion Service (12), Municipal Service Council of LGBT (28), Municipal Service Council for the Elderly (29) and the Service of Communication, Documentation and Marketing (30). It transpired that this case is less advantageous. The extreme compatibility values are 70% for the Catalan Language Promotion Service and the Service of Communication, Documentation and Marketing. On the other hand, 29% for two pairs of services: the Municipal Service Council for the Elderly and the Council Tax Service, as well as the Municipal Service Council for the Elderly and the Service of Citizen Attention. The average compatibility value calculated by arithmetic mean of all compatibility values for the six services (Table 5) is equal to 41% $\left(\frac{45\%+35\%+43\%+29\%+52\%+35\%+38\%+29\%+34\%+41\%+41\%+70\%+56\%+31\%+31\%}{15}\right)$. Thus we can consider the general compatibility of this combination of services as rather poor.

4. Discussion

The presented method allows us to obtain a percentage value of compatibility between municipal services. However, there are some concerns that are important to recognize, and may have a substantial influence on the final results.

The most significant issue to stress is that service compatibility is context-sensitive. It cannot be considered in isolation without the surrounding environment. The context co-creates the service and is responsible for its unique character. However, the socio-political and economic environment changes in both, i.e. space and time. For this reason service compatibility is not transferable. Two services may be highly compatible in one city context, but corresponding services in another city may have a totally different compatibility value. A primary school service, for instance, is highly standardized. However, in spite of this, every instance of this service may have a different characteristic according to the context in which it is situated. This difference will translate in distinct attribute values and eventually the final compatibility result. For this reason we assess very specific service instances, instead of encapsulated categories of services. Similarly, service compatibility calculated today may change dramatically in years or even months to come, along with changes of the environment. This is why compatibility assessment should not be a one-time event, but rather a regularly repeated process.

Another important point is that the result of compatibility assessment is expressed as the area ratio of two polygons. We consider this way of calculation the most appropriate in general terms since it reflects well the extreme values. Yet again, depending on the particular city context, some features may be more important for the decision maker than others. In such cases another type of calculus, such as weighted arithmetic mean, may be considered more suitable.

Moreover, the features described in Sections 2.1.1–2.1.7 are, in our opinion, the most important ones and appropriate for the purpose of defining service compatibility. However, the method is flexible, thus the number of features, as well as the number and type of attributes (binary/relative) can be modified according to the current needs and context requirements. Such changes do not affect the model, and the way of calculating the compatibility remains the same.

Table 5
Compatibility matrix for 30 sample services. All values in %.

	Municipal Service of Territorial Analysis	Municipal Habitat Service	Council Tax Service	Service of Citizen Attention	Service of City Historical Archive	Service of Image Research and Dissemination	Tourist Office Service	Municipal Employment Service	Library Service "Antònia Adroher"	School Library Service "Montfollet"	Public Library Service "Carles Rahola"	Catalan Language Promotion Service	Service of City History Museum	Civic Center Service "Sant Narcís"	Municipal Market Service	Youth Center Service "Els Quimics"	"La Caseta" Educational Service	Service of Municipal Music School	"l'Olivera" Nursery School Service	Service of Adult Education	Migdia Primary School Service	"Font de l'Abella" Service of Special Education	Service of Municipal School of Art	Santa Eugènia - Can Gibert del Pla District Swimming Pool Service	Santa Eugènia-Montfalgars District Sports Pavilion Service	Youth Health Service	"La Sopa" Homeless Shelter Service	Municipal Service Council of LGBT	Municipal Service Council for the Elderly	Service of Communication, Documentation and Marketing
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
1.	100	40	42	28	35	40	36	39	17	6	34	42	28	16	23	17	21	17	2	33	5	13	24	13	11	18	17	45	29	42
2.	40	100	50	46	43	35	37	47	23	10	35	45	38	44	38	43	30	24	12	40	9	24	26	21	15	43	59	77	60	36
3.	42	50	100	45	36	39	44	40	17	7	29	35	28	22	31	17	21	18	6	37	6	16	20	17	13	17	31	43	29	52
4.	28	46	45	100	51	43	44	43	30	18	42	35	47	33	46	31	51	47	31	61	30	46	49	38	33	31	48	38	29	34
5.	35	43	36	51	100	81	79	50	59	42	84	60	81	43	50	39	46	39	18	56	20	35	46	31	26	36	44	40	26	42
6.	40	35	39	43	81	100	81	43	54	39	80	50	83	34	39	37	43	38	16	50	18	32	46	32	27	36	33	36	18	42
7.	36	37	44	44	79	81	100	38	50	36	77	46	74	39	47	34	40	34	14	48	15	30	38	29	22	31	41	33	17	45
8.	39	47	40	43	50	43	38	100	28	18	47	40	40	32	56	36	36	32	15	54	16	31	38	25	25	39	38	53	34	25
9.	17	23	17	30	59	54	50	28	100	62	57	39	58	54	38	29	36	28	34	37	37	25	33	46	39	24	29	20	17	21
10.	6	10	7	18	42	39	36	18	62	100	46	30	46	41	21	44	42	41	55	28	59	43	37	37	36	31	19	10	6	14
11.	34	35	29	42	84	80	77	47	57	46	100	52	80	40	48	45	50	44	20	55	23	39	54	35	33	45	42	40	24	35
12.	42	45	35	35	60	50	46	40	39	30	52	100	53	25	37	31	35	31	11	38	14	30	32	17	14	28	33	41	41	70
13.	28	38	28	47	81	83	74	40	58	46	80	53	100	36	44	43	51	44	23	47	25	39	50	33	26	40	39	34	23	35
14.	16	44	22	33	43	34	39	32	54	41	40	25	36	100	42	46	35	28	43	40	37	25	31	51	44	41	54	37	27	10
15.	23	38	31	46	50	39	47	56	38	21	48	37	44	42	100	38	44	38	21	48	22	38	40	31	26	37	50	32	27	24
16.	17	43	17	31	39	37	34	36	29	44	45	31	43	46	38	100	61	65	37	46	40	54	57	28	29	78	50	45	37	14
17.	21	30	21	51	46	43	40	36	36	42	50	35	51	35	44	61	100	84	46	69	50	74	85	47	45	52	39	29	25	17
18.	17	24	18	47	39	38	34	32	28	41	44	31	44	28	38	65	84	100	48	68	59	79	84	44	43	50	34	25	21	14
19.	2	12	6	31	18	16	14	15	34	55	20	11	23	43	21	37	46	48	100	33	75	57	43	53	53	29	32	8	9	6
20.	33	40	37	61	56	50	48	54	37	28	55	38	47	40	48	46	69	68	33	100	42	55	73	45	42	40	45	43	23	22
21.	5	9	6	30	20	18	15	16	37	59	23	14	25	37	22	40	50	59	75	42	100	65	48	55	55	30	20	8	7	6
22.	13	24	16	46	35	32	30	31	25	43	39	30	39	25	38	54	74	79	57	55	65	100	69	41	39	49	35	24	22	15
23.	24	26	20	49	46	46	38	38	33	37	54	32	50	31	40	57	85	84	43	73	48	69	100	46	49	56	36	31	22	15
24.	13	21	17	38	31	32	29	25	46	37	35	17	33	51	31	28	47	44	53	45	55	41	46	100	87	30	27	21	10	8
25.	11	15	13	33	26	27	22	25	39	36	33	14	26	44	26	29	45	43	53	42	55	39	49	87	100	34	21	22	9	7
26.	18	43	17	31	36	36	31	39	24	31	45	28	40	41	37	78	52	50	29	40	30	49	56	30	34	100	52	49	37	14
27.	17	59	31	48	44	33	41	38	29	19	42	33	39	54	50	50	39	34	32	45	20	35	36	27	21	52	100	46	43	22
28.	45	77	43	38	40	36	33	53	20	10	40	41	34	37	32	45	29	25	8	43	8	24	31	21	22	49	46	100	56	31
29.	29	60	29	29	26	18	17	34	17	6	24	41	23	27	27	37	25	21	9	23	7	22	22	10	9	37	43	56	100	31
30.	42	36	52	34	42	42	45	25	21	14	35	70	35	10	24	14	17	14	6	22	6	15	15	8	7	14	22	31	31	100

5. Conclusions

Municipal service provision is a key aspect of city management. However, recent literature suggests that they are not sustainable and their performance should be optimized. This optimization should begin from the appropriate adjustment of the surface available in facilities to the spatial needs of services. For this reason, our focus was on the issue of municipal services compatibility for the sake of their efficient combination in Multi – Service Facilities.

First, we defined two fundamental concepts: a service and a facility. We described them and stressed the difference, summarizing that, in short, a service is an intangible content of a physical container – facility. Next, three types of relationships between services and facilities were identified: 1) one service offered in one facility; 2) one service offered in various facilities; 3) various services offered in one facility (MSF).

Subsequently, we proposed a method of calculating the degree of compatibility between municipal services. The method comes down to the service description via seven features (Affiliation, Delivery, Nature, Presence, Scope, Stakeholder and User), and posterior calculus of their values applying the City-block distance formula. The proposed method has been tested on a pilot project with 30 services from the city of Girona. Each service was described quantitatively. Next, the compatibility of each service with each one was calculated using a normalized City-block formula. The compatibility results were illustrated graphically on the radar charts and the total compatibility results were presented in the compatibility matrix. Subsequently, the results were grouped into four sets depending on their degree of compatibility, from services strongly compatible to those that are incompatible. Posteriorly the method of calculating the degree of compatibility was also used to evaluate two identified cases of MSF indicating strong compatibility in the first case and poor compatibility in the other. Doing this, we positively verified the hypothesis stated at the beginning of this article, confirming that it is indeed possible to establish the degree of compatibility between municipal services.

Moreover, we came to the conclusion that MSF is a desired solution for the optimization of city resources. It allows a more efficient land usage and always creates added value when combined services are compatible, one to another. The value is created in two ways: by decreasing the cost of service provision (the administration perspective) and increasing the quality (end user perspective).

The municipal administration may save money due to a more efficient facility usage increasing the occupancy rate. This reduces the energy consumption and maintenance cost. Well combined services and more efficient facility usage may render new facility construction unnecessary. Moreover, shared facility use requires less staff to maintain. It may also simplify logistical processes, especially in services where exchange of information and/or objects is frequent and essential.

On the end user side, the value added is created due to the user-friendly arrangement of services. Thanks to this, citizens can use more than one service during the same visit. They also spend less time on travelling from one facility to another. This positively impacts the city traffic as well as other related areas such as parking and technical utilities.

In summary, in this article our focus was on the compatibility of municipal services for the purpose of their advantageous combination in Multi-Service Facilities. However, the problem domain is very extensive and the possibilities of public facilities and services performance improvement are much broader. Therefore, we theorize that the framework application should be parallel with other e-government initiatives, especially the process of public services virtualization that contributes to spatial efficiency. Additionally, the use of the presented method is not limited exclusively to municipal services, but can be adapted and applied to any kind of services. In particular, we postulate future extension of this exercise by including private sector services that could be offered together with public ones, to support the public-private partnership.

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Discussion

This section concludes the thesis and discusses the main findings. The major contribution of this thesis is the creation of a framework for space-use efficiency in public facilities consisting of two key elements: a new method for space-use analysis based on the average number of users present at any moment, as well as a method for determining the compatibility of public services based on service similarity. These two contributions are discussed in the following subsections.

Space-use analysis

The proposed method for space-use analysis determines the actual demand for space. It is low-cost, non-expert and requires relatively small amounts of data; but most of all this method is distinguished by a service (or more specifically an activity) approach. This is an important difference because space should not be assigned to the person according to their status or position in the organization, but should be allocated more flexibly according to the type of activity and the needs of its user (Wiggins, 2010). This is because activities are the focal point of any service, and omitting any user activity can mask the real space needs (Kim, 2013). An activity is defined as a unit of work having explicit duration, a relationship with other activities, cost and resource consumption (Business Dictionary, 2016). Thus, the difficulty of maximizing the efficiency of space use is to allocate the number of activities to the available space (Liggett, 2000). This task is particularly challenging in the case of irregular activities, and those with regard to which the number of users is not determined, and may be considered as random.

The determination of the amount of space that is needed for the purpose of the service under consideration is much easier for designated spaces, where it is assumed that the workplace or specific area is occupied by a person on a full-time basis, regardless of whether or not the person is actually present. For such cases the Assignable Square Feet (ASF) or Assignable Square Meters (ASM) value per work station can be used (Facilities Services, 2009). This value has to be multiplied by the number of users (work stations) assuming they are occupied full time. The resulting number of spaces is subsequently compared with the area available. Ideally the comparison should look as illustrated in Figure 1.

Figure 1. Illustration of matching service activities with corresponding facility areas. Source: Rusek & Colomer-Llinàs, 2016.

The situation presented in Figure 1 is an ideal and is not likely to occur in the real world. The correlation between activities and corresponding facility areas has been exemplified in a real case study. For this purpose, the academic research service that takes place in the research facility building of the Polytechnic School at the University of Girona has been analyzed. The initial assignment of activities and corresponding facility areas is presented in Figure 2.

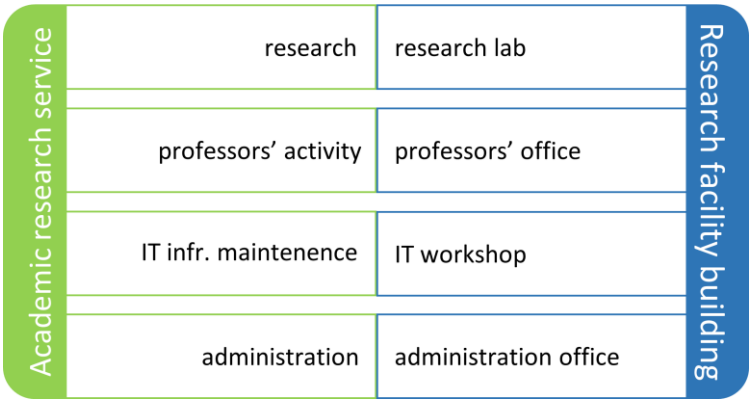

Figure 2. Service activities matched with corresponding facility spaces. Source: Rusek & Colomer-Llinàs, 2016.

However, after having determined the space needs for every activity and compared the obtained values with specific spaces, the final result turned out to be far from the ideal, as depicted in Figure 3.

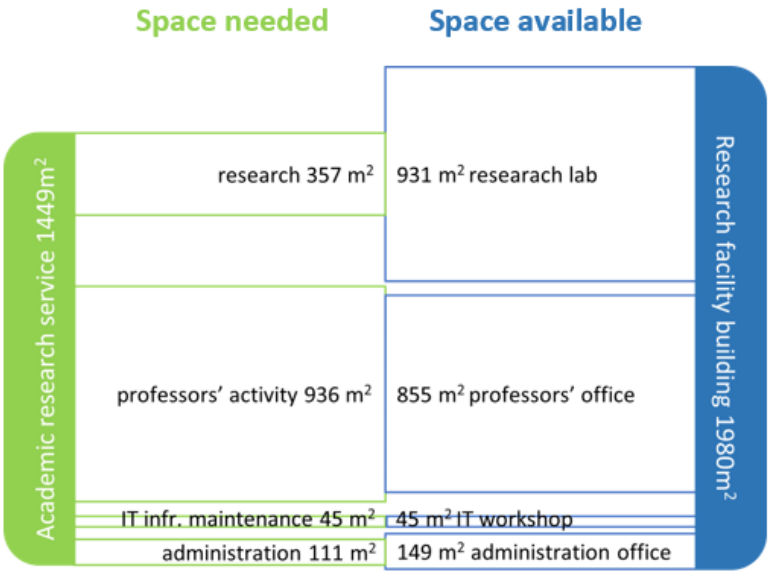

Figure 3. Proportional matching of space needed and space available in the research facility building. Adapted from: Rusek & Colomer-Llinàs, 2016.

Figure 3 presents a significant discrepancy between space demand and space offer. It is possible to obtain such a visualization for designated spaces. For non-designated spaces, the variation in terms of irregular activities, varying number of users and changing space needs make such visualization difficult. For this reason, in such cases, results are provided in form of a utilization rate which is more convenient.

Another important issue which must be considered regarding the method for determining space needs is the decomposition of service and facility. Facility decomposition is an easier and more obvious task since a facility is a tangible, physical object that can be measured. The decomposition of service, however, is not so simple, due to its intangible nature. To this end the concept of service granularity has been described in Rusek & Colomer-Llinàs (2016). Service granularity helps in defining an appropriate level of service decomposition. It is especially important in the case of complex services where the difference between service, subservice and activity may not be clear. For this reason, the concept of Business Value Granularity (BVG) used in Service Oriented Architecture (SOA) can be applied. According to the BVG, each service should fulfill some business goal (Haesen et al., 2008). In line with this, every public service should fulfill a particular public administration goal, otherwise it can only be considered as a sub-service or, in other words, a secondary service. For instance, a catering service usually forms part of the education service offered in a school facility. However, it does not fulfill the main education goal but rather has a supportive function. Thus, in this case, catering would be a good example of a sub-service. Furthermore, every service can be decomposed to its basic activities. Yet, service can be also decomposed on the basis of Business Process Modelling (BPM). The process maps obtained in this way are a very valuable tool for service decomposition since they denote the set of activities that have to be carried out to achieve a particular objective, and provide a graphical representation of how the organization operates (Davenport, 2005).

Another important issue that should be stressed is that the method for determining space needs is very flexible, and can be applied to evaluate the space needs of almost any service. However, the usefulness of this method is limited in the case of museums, art galleries or archives. For these types of facility, usually only a fraction of space is devoted to peoples' activities (visiting or consulting), while the greatest part is occupied by exposition or volume collection. In addition, space required for every type of exposition is very individual since sometimes space itself forms part of the exposition. This is what happens frequently, especially in historic buildings.

Yet one more remark is that this method for facility optimization is focused on the space aspect exclusively and does not take into account other related features such as equipment,

furniture or other commodities necessary for specific type of activities. This is because the method has to be flexible and applied to a variety of services in general, while matching activities with spaces of specific characteristics, happens at the lower level of detail. In addition, this issue has already been investigated by Kim (2013).

Finally, the method uses historic data encompassing larger periods of time to determine space utilization. However, space needs may change more frequently. For this reason, increasing the frequency of the inclusion of data samples may provide more accurate results and allow us to compare how space needs change over time. In addition, the method provides information on space-use based on data covering past periods. However, it does not provide any information on how the needs may change in the future. This is difficult to predict due to the variety of different factors affecting space-use and is problematic when it comes to determining such aspects as political change, natural disasters or sudden economic fluctuations

Service compatibility

Service compatibility analysis allows for a more efficient space-use by introducing additional compatible services and repurposing existing single-service facilities, converting them into multi-service facilities. The value is created in two ways: by decreasing the cost of service provision (the administration perspective) and by enhancing service conditions (the end user perspective). The proposed method for defining service compatibility based on feature modelling is very flexible. The set of features proposed in Chapter 3 aims to characterize a service in the most comprehensive manner. However, the type of the features and their number, as well as the number of attributes, is flexible and can be adapted according to current needs or objectives. This has been presented in Rusek & Colomer-Llinàs (2017), where the method has been applied for user-centered analysis of service compatibility, taking into account the user perspective as dominant, without considering the administrative point of view. This approach assumes that citizens are not only passive receivers but also active co-creators of public services, and their inputs should be taken into account during the decision making process on service arrangements. To this end only services where the users'

presence is necessary were taken into account. In this new set-up a set of eight features that describe a service from the users' perspective has been defined: Age, Sex, Location, Approach, Frequency, Day part, Week part and Nature. Additionally, the features were organized in three segments used in marketing, corresponding to the users' demography, geography and behavior.

Demographic Features

Demographic features characterize the service users regarding their Age and Sex. The Age feature is divided as follows: children (0-14 years), youths (15-26), adults (27-60) and the elderly (60+), which reflects the age structure of service users. Similarly to the Age feature, Sex represents the proportional gender distribution of the service users, classifying them as either female or male.

Geographic Feature

On the subject of geographic location, the location of users regarding the situation of a particular service is considered as a relevant feature for service arrangement. The Location feature differentiates service users in terms of neighbors, in cases where a service is dedicated to the local community; citizens, where the service is used equally by all city inhabitants; commuters, where the service is used by people who live outside the city area but come to it regularly for different purposes; and finally services that can be used by visitors – people who are not related to the city but stop over for other purposes than living, studying or working.

Behavioral Features

The behavioral features (Approach, Frequency, Day part and Week part) characterize the manner of the users' interaction with a service.

The Approach feature has two attributes: push and pull. A service is seen as a push service when its users are obliged to use it, but have no internal motivation for doing so. A municipal council tax could be a good example of a push service. On the other hand, pull services are those that are used as a result of a user's internal motivation. They attract consumers because they offer some kind of benefit: either the service itself is joyful (e.g. cultural services) or its outcome is beneficial (e.g. healthcare).

The Frequency feature reflects the regularity of the users' interaction with the service. They can attend the service either regularly, from time to time, or sporadically.

The Day part feature depicts at what time of the day a service receives its users; whether it is in the morning (8-12h), midday (12-15h), afternoon (15-18h) or evening (after 18h).

Similarly, to Day part the Week part feature reports on the proportions of users attending the service on weekdays and weekends respectively.

In addition, the Nature feature does not belong to any user segment (demography, geography, or behavior) but stays apart. In contrast to the other features, it does not describe service users, but reflects a user's perception of a service. In other words, it says how a service is seen by its users who classify it according to the following attributes: administration, culture, education, health care, safety & protection, social, sports, transport and commercial. It is a user-centered response to an administration-centered point of view, which classifies services according to the department or entity that is responsible for its provision. All features of the user-centered compatibility of services have been summarized in Table 1.

Table 1. Summary of the user-centered feature model with attributes.

Segment	Feature	Attribute
Demography	Age	children, youth, adults, elderly
	Sex	female, male
Demography	Location	neighbors, citizens, commuters, visitors
Behavior	Approach	push, pull
	Frequency	regularly, from time to time, sporadically
	Daypart	morning, midday, afternoon, evening
	Weekpart	weekday, weekend
User´s perception of service	Nature	administration, culture, education, health care, safety & protection, social, sports, transport, commercial

Such a modification of the feature model allows a change in the perspective and assessment of services based on different factors in order to obtain a distinctive point of view. The set of features can be modified freely depending on the approach and objectives of the compatibility analysis.

Conclusions

The main contribution of this thesis is the development of a framework which encompasses the activity-centered method for determining space utilization in numerous public facilities, and a quantitative method for defining service compatibility. The combination of these two methods aims to increase space efficiency and enhance services by repurposing existing facilities and converting them into multi-service facilities.

Chapter 1 described the link between public services and facilities, and characterized the main issues responsible for their low efficiency. The different administrative bodies responsible for facilities planning and service programming, the lack of entrepreneurship in the public sector, and the changing environment, are the main factors causing maladjustment between the space available in public facilities and the space needs of the service or services offered under their roof. Furthermore, the framework for space-use efficiency and for the arrangement of public services has been presented, and its parts described and discussed. The chapter concludes with the benefits of the framework in terms of every group of city stakeholders: citizens, NGOs, private companies and public administration.

Chapter 2 described and compared different methods of space-use analysis: the Guidelines approach, Benchmarking, the UFO method and Computer Aided Facility Management. It also discussed the advantages and disadvantages of each of these methods in the context of evaluating public facilities. Furthermore, it proposed a new method for determining space needs which is more advantageous for the public sector than the others. It is a low-cost and non-expert approach based on determining the average number of users present at any moment. Subsequently, all methods have been tested on the same dataset and the results revealed that the proposed method for

determining space needs has comparable precision as the UFO method but is more suitable for the public sector due to its flexibility and the lower amount of data that is necessary. The method allows organizations to obtain situational awareness of space utilization in multiple public facilities, and helps identify and focus future actions on facilities where the discrepancy between space demand and space supply is greatest. This significantly decreases the time and cost of facility evaluation due to the reduced number of cases that require in-depth analysis.

In chapter 3 a quantitative method for determining service compatibility is proposed and described. The method is based on feature modelling and a quantitative description of the evaluated services. All features - User, Nature, Presence, Scope, Affiliation, Stakeholder and Delivery - have been characterized. The calculus of the distance between particular features of two services have been presented. In addition, the method has been tested on the example of thirty public services in the city of Girona. The quantitative description of all services have been presented and the results depicted on a compatibility matrix. Regardless of the final percentage value of service compatibility, the relationship between services in all features has been represented in the form of radar charts to allow an organization to visualize the correlations and make the results interpretation more intuitive.

The presented research deals with the problem of more efficient space-use in public buildings. Nevertheless, the subject has not been exhausted. There is still much to do on this matter in the future.

First of all, the research exclusively focuses on public services and facilities. However, in future, its scope can be extended by including private services and investigating the best way of combining public services with private ones.

Moreover, the issue of service combination can also be approached from a user-centered perspective by uncovering sequences in citizens' interaction with services (both public and private). Discovering sets of services that are used in a close time proximity, one after another, would indicate how they could be reorganized in a more user-friendly way. This would be especially helpful to identify services that are compatible on the basis of complementarity.

Another issue is that in terms of the service-facility relationship, only the spatial dimension has been considered. However, the framework can be enhanced by including additional aspects such as the requirements for specific types of equipment, furniture or accessibility, etc. which would increase the functionality of the framework.

Finally, the framework, with its all functions, should be implemented to constitute a finished tool that can be integrated with other decision making tools.

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