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

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Abstract

This article focuses on the issue of a sustainable space-use in public facilities and beneficial arrangement of services. Uncorrelated facility planning and service programming as well as environmental factors cause discrepancies between space demand and space supply leading to space overuse or underuse. To enhance the functional and economic efficiency of public facilities a conceptual framework, which is a planning and evaluation tool for decision support, is presented and discussed on examples. The framework consists of two decisive elements: space-use analysis and service compatibility analysis. The first one aims to determine the degree of space utilization in multiple public buildings while the latter reports on how services are related to each other in terms of their compatibility. The article explains these concepts in details on examples.

Keywords

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

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Introduction

In our time cities became a driving force of European development (Rotmans, van Asselt & Vellinga 2000). They compete with each other for private finance and investments (Kourtit, Nijkamp, & Partridge, 2013). For this reason, numerous initiatives aim to measure, benchmark and compare them, such as: European Smart Cities (Vienna University of Technology, 2007), City Benchmarking Data (Citybenchmarkingdata.com, 2017) or Best Places (Bestplaces.net, 2019), to name a few. The competition takes place especially in the field of public services due to their direct impact on citizens' quality of life (Lee & Lee, 2014). In this context, a service is understood as an intangible process or activity provided by the public authority on behalf of citizens and offered in a facility – a built, indoor environment. Thus, the quality of public services depends, in great part, on facilities – buildings where those services are offered. This indoor environment should support performance of public services (Kwok & Warren, unpublished report, 2005) and its structure must assure appropriate spatial conditions for all service activities (Wiggins, 2010). However, public services are constantly affected by a number of external factors, such as social, economic, political and environmental which impacts the services changing number of activities for which space expansion or reduction is necessary. Facilities, as built environment, are not very prone to such changes. In consequence, there are many examples of facilities and services that do not fit each other spatially causing inefficiencies and citizen's dissatisfaction (Marsal-Llacuna, 2010).

Taking into account a changing environment, the number of public facilities and the variety of services offered on the scale of a city, it is a big challenge for the public sector in terms of how to manage this set of services and buildings (Zhang & Gao, 2010). In consequence there is little awareness about the space resources available in numerous public facilities. The service-space adjustment is usually carried out at the level of specific buildings, however there is a lack of general awareness on space resources at the scale of the entire city.

The issue of space-use is not new and has been in interest of researchers and organizations for decades. A significant improvement in this field have been brought by Pennanen (2004) who studied relation of work space and user activity. Moreover, Kim and Fischer (2014) automatized the process of space-use analysis using ontology with specific focus on educational buildings. Both contributions are focused on a detailed analysis of building areas of specific facilities. However, to the authors' best knowledge there is a lack of studies focused on a set of buildings of different types and characteristics – a typical amalgamation in a city context.

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 (Ibrahim, Yusoff, & Bilal, 2012). Kim, Cha & Kim (2016) illustrated this matter on the example of a higher education facility in the United Kingdom which uses annually 318 kWh per square meter on average. 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.

To this end, the framework for space-use efficiency and arrangement of public services has been proposed. The purpose of this framework is to enhance space-use (functional and economic efficiency) in public buildings. It is intended as a decision-support tool for city governments since management of public facilities is usually fragmented, limited to specific buildings or subsets of buildings. Therefore, a holistic overview on all city facilities may provide a significant difference to support a knowledge-based decision making. For this reason, the framework aims to: first, provide situational awareness on space-use on multiple public buildings of different types; second, identify underutilized buildings; and third: recommend how to combine compatible services with the existing ones, converting traditional single service facilities into multi service facilities and by this mean increase utilization rate and improve efficiency.

Multi service or multipurpose facility (MSF) combines different services under one roof and permits more than one activity to take place at the same time and location (Batty, Besussi, Maat & Harts, 2004). It also reduces the amount of urban land necessary for provision of public services (Marsal-Llacuna, Leung & Ren, 2011). According to Suzuki and Hodgson (2003) MSF can improve the level of service and cost-efficiency because combination of various services supports the economies of scale effect. For this reason, MSFs are widely practiced in public sector especially in high density areas (Batty, Besussi, Maat & Harts, 2004), where land prices are very costly (Suzuki & Hodgson, 2003). In these parts, there are many examples of numerous services being allocated in one facility. The substantial difference, however, is that those facilities have been usually designed as MSF from conception. Reversely, the framework proposed in this paper aims to create MSFs by taking advantage of existing buildings and retrofitting them with additional and compatible services.

Theoretical background

This paper contributes to the state of the art by filling the gap between three well studied issues: facility location problem on the one side and facility layout as well as scheduling problem on the other.

The purpose of facility location problem is to find optimal place for facility construction assuring good accessibility and minimizing costs. This topic has been widely studied especially in the field of operations research (Shmoys, Swamy & Levi, 2004), for example by Teitz (1968), ReVelle (1987), or Athanasiou & Photis (unpublished report, 2004).

On the other hand, facility layout problem seeks for the best arrangement of spaces and activities within the building (Drira, Pierreval & Hajri-Gabouj, 2007). It is used in the design phase for allocation of space in new buildings or to repurpose space in the existing ones (Liggett, 2000). There are numerous studies dealing with this issue, for example by Kusiak & Heragu (1987), Meller, Narayanan & Vance (1998), or Saraswat, Venkatadri & Castillo (2015). Furthermore, the scheduling problem is a decision-making issue that is applied in manufacturing and service industries to deal with allocation of resources and tasks over given periods of time (Pinedo, 2015). This topic has been studied also in the facility management context, for example by Gupta & Gupta (1988), Thabet & Beliveau (1994), or Zhao et al. (2014).

The proposed framework fills the gap between these three subjects. It does not consider the process of building and locating new facility but instead it focuses on facilities that have been built and used already for some time. Furthermore, it analyses a set of buildings indicating those where utilization is far from optimal and proposes compatible services to be combined with the existing ones instead of focusing on particular buildings in details (which is a domain of facility layout as well as scheduling problem). Consequently, it does not interfere into internal building structure or the task organization, however the outcome of the framework may provide an indication for internal layout or scheduling redesign.

The basic assumption of the framework is a logical separation of service (the intangible component) from facility (the physical component). Habitually, facility and service are considered as one entity (e.g. a school). However, it is necessary to break this association and think of service and facility as of two independent items that should coexist together, e.g. school – building, and school – service of education, as depicted in figure 1. The independent approach for facilities and services allows for a more flexible and efficient space-use based on combination of different services in one facility creating MSF. Combination of compatible services is vital because as Lee and Lee (2014) claim, in most cases, the way that services are arranged reflects the internal structure of public administration without considering functional relations between services which have a significant influence on productivity and service quality. For this reason, compatibility analysis should precede decision making on service arrangements whenever various services are planned to be offered together.

Appropriate arrangement of services resulting in a more efficient space-use require previous situation (or situational) awareness (SA). SA allows obtaining a clear image of the current state of affairs that is indispensable for accurate decision making (Gheisari & Irizarry, 2011). It has a potential for facility management because it provides mental picture of the situation and helps in making more accurate decisions based on information that lead to improved performance; otherwise less than optimal decisions are made (Gheisari & Irizarry, 2011). SA in the context of decision making has been depicted in Figure 2.

Decision support framework

Efficient management of public facilities and services requires a holistic approach encompassing legal, managerial, social and technological instruments. Local governments have not enough power to deal with all these issues and therefore ad-hoc solutions are applied to mitigate negative effects of this unfavourable situation. This, in practice, translates into optimization that usually considers only economic aspect and is narrowed to cost reduction (Pym, Taylor & Tofts, 2007). For this reason, the presented framework is an evaluation and planning tool allowing analysing two types of relationships: service-facility and service-service, on numerous public facilities. It consists of two decisive processes that correspond to each type of relationship. Space-use analysis reflects the service-facility relationship and allows for determining current space utilization – a crucial information for enhancing space economic efficiency on the one hand, and assuring appropriate amount of space for all activities, on the other. Service compatibility analysis reflects the service-service relationship and reports on how services offered in one facility (or planned to be offered in one facility) are related to each other in various aspects – a crucial information for service beneficial arrangements.

As depicted in Figure 3, the framework consists of four processes (data insertion, space-use analysis, service compatibility analysis and decision making), one decision point (verifying the number of services) and data repository (space-use inventory). At the process' initial phase, data about facility area and quantitative description of service or services is necessary. This information may be inserted manually or imported automatically if such a repository is available. Next, the number of services is verified. If more than one service is offered within the facility, compatibility analysis is performed and posteriorly, space-use analysis is executed. These processes are performed automatically to provide information about how services are related to each other and what their spatial needs are. The results are stored in a space-use inventory and the process repeats for all considered facilities. Finally, the outputs set up a basis for the aware decision making and are delivered to the decision maker. The key elements of the framework: space-use analysis, compatibility analysis, space-use inventory and decision making are described in details in the following sections:

Space-use analysis

Space-use analysis aims to determine service space needs and contrast them with facility primary area where the service can be offered. It is important to stress that space-use has to be considered not only from the economic point of view, but also the environmental impact has to be taken into account. According to van den Dobbelsteen and de Wilde (2004) space-use is strongly correlated with: use of building materials, energy and water consumption, travel, ecology, health and safety. For this reason, determining factual space needs is essential for economic as well as environmental reasons. The process of space-use analysis has been depicted in Figure 4.

At the beginning of the space-use analysis process, facility and service are evaluated independently. Facility has to be decomposed and the net internal area (NIA) - space available for service provision - is taken into account (space supply).

Simultaneously, the service is decomposed to its activities. Each activity is characterized by its type, duration and number of users. Based on this data, spatial requirements are determined (space demand). Subsequently the two values are compared. If space demand corresponds with space supply, the facility is performing well in terms of space efficiency (space conformity). Otherwise there are some discrepancies that may take two forms: space scarcity or space excess. The first one occurs when space demand surpasses the space supply. This of course is not a desired situation because lack of space affects conditions of service provision preventing it from performing its full potential. Space scarcity is relatively easy to detect because usually service directors complain about it. The other form of discrepancy occurs when facility offers more space than is required by service or services hosted within. In such case facility satisfies the service spatial requirements fully but is not economically efficient since space excess can be considered as waste of resources. It is not so easy to detect since people's needs are unlimited and service directors usually are not willing to report on having too many resources unless they are rewarded for it. Thus, the determination of space needs has to be done in a more objective way using specific standards, such as Occupant Load Factor (OLF) or even Space Syntax in case of more complex facilities.

Subsequently, regardless the case (space conformity, space scarcity, space excess), facility utilization rate is determined and results are presented for decision making. The space-use analysis process has been exemplified on the research facility building of the Polytechnic School of the University of Girona. Activities that take place in the facility were determined (research, professors´ activity, IT infrastructure maintenance and administration) and assigned to the corresponding spaces (research lab, professors´ office, IT workshop and administration office). Space demand has been calculated by multiplying the number of users (participants) of every activity by appropriate Area Per Person Factor (APPF). The value of this Factor was taken from the Space Planning Guidelines (Facilities Services, 2009) and assigned to each activity. Posteriorly, space demand and space supply have been calculated and their values compared. This is presented in Table 1. The results of this exercise show space scarcity for professors´ activities (-81.3 m^2), space equilibrium in case of IT infrastructure maintenance (0.05m^2) and space excess in case of administration (37.9 m^2) as well as research (572.4 m^2) activities. Considering the abovementioned values, the research facility building has a significant overall space excess (529 m^2). The most intuitive conclusion from this study is that the building requires internal layout redesign to satisfy spatial requirements of the professors´ activities and moreover has plenty additional space that could be utilized for other purposes. The final result can be also expressed in terms of utilization rate as a proportion of space demand and space supply giving the result of 73%.

Service compatibility analysis

Service compatibility analysis is a quantitative method of service comparison. Services are compared in various aspects that characterize them in a comprehensive way from different perspectives. Rusek et al. (2016) propose the following set of seven features which describe a service from both: user as well as administration perspective:

Features describing a service from the user perspective:

- User – describes the proportional age structure of service users: Children, Youth, Adults, Elderly.
- Nature – reflects a character of service from the user perspective: Administration, Culture, Education, Health care, Safety, Social, Sports, Transport
- Presence – refers to the mode in which a service is delivered: In person (for services which require in person presence of the citizen in a facility) and Virtual (for services which can be delivered online)
- Scope – refers to service accessibility. Service can be classified as Local (when it is design to serve to local community, e.g. district library), or Global (when it is dedicated to all city inhabitants, e.g. hospital or administrative services)

Features describing a service from the administration perspective:

- Affiliation - represents an administration department responsible for service provision. This characteristic depends strictly on the context of a particular city due to different organizational schemes.

- Stakeholder – refers to all people who are involved in the service; not only its final users, but also service staff and other, indirect participants. Alike the User characteristic, Stakeholder reflects the age structure: Children, Youth, Adults and Elderly.
- Delivery – refers to the mode of service, which can be a Front office (e.g. social service with citizen attention), or Back office (e.g. administration).

Each of these characteristics has to be expressed quantitatively by assigning a compositional value to each attribute. This value represents the degree to which the attribute defines the service. For instance, if children are 80% of service users and adults 20%, the compositional values of these attributes would be 0.8 and 0.2 respectively. Posteriorly, the distance between corresponding values of two services is calculated to determine the degree of their coincidence.

For that purpose, we take advantage of the City-block distance which represents a distance between two points as a sum of the absolute differences of their coordinates (Panigrahi, 2014). The general City-block distance formula has to be normalized to represent the final result as a percentage value instead of a number between 0 and 1, and it takes the following form:

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

To obtain the percentage value that reflects the degree of similarity, let us consider for example a user characteristic of two hypothetical services: Service 1 and Service 2. To obtain the degree of their similarity, the values form Table 2 has been substituted into the normalized City-block distance formula, as follows:

$$d(S1, S2) = 100\% - (\frac{1}{2}\,(|32\% - 25\%| + |50\% - 25\%| + |10\% - 25\%| + |8\% - 25\%|)$$

$$= 100\% - \frac{1}{2}(7 + 25 + 15 + 17) = 100\% - \frac{1}{2}\,64 = 68\%$$

Thus, similarity of the user feature of Service 1 and Service 2 is equal to 68%. Values of other characteristics are to be calculated in the same way. The results obtained for all characteristics provide an overview of the total degree of similarity between Service 1 and Service 2. The overview of the process of service compatibility analysis is presented in Figure 5.

The result of service compatibility analysis is a percentage value representing to what degree the services are ‘of their kind’. The higher the coincidence, the higher probability of advantageous combination. To exemplify this, a thirty municipal services were selected from the city of Girona, Spain based on their diversity, to demonstrate services of different types and characteristics. To this end, the sample include: cultural, education, administration, social, sport and heath care services. The finale result of compatibility analysis is depicted in Figure 6 in compatibility matrix.

Compatibility matrix indicates what services are compatible and could be offered together (values close to 100) and services which combination should be avoided (values close to 0). The compatibility value provides a common denominator for comparison of different combinations of services. It does not establish fixed ranges of compatibility but settle which combination of services is more adequate. For instance, if compatibility degree of Service x and Service y is 67%, and compatibility of Service x and Service z is 76%, it means that combination of services x and z is more recommended because the degree of their compatibility is higher. However, it would be improper to say that service x is compatible with service z but incompatible with service y. Thus, the matrix visualizes compatibility of various services helping in taking decision on service (re)arrangements to favour advantageous combinations and discriminate the unfavourable ones.

Space-use inventory

Space-use inventory is the outcome of the space-use analysis process and compatibility analysis process. It contains information about space utilization in multiple public facilities and characteristics of services offered within. This information is presented in a visual and user-friendly form using Google Maps API as depicted in Figure 7, where location of five evaluated facilities has been represented spatially by markers. Facilities have been clustered into four quarters and highlighted with a corresponding colour: Q1 - high utilization (over 75%), dark-green colour; Q2 - mid-high utilization (between 50% and 75%), light-green colour; Q3 - mid-low utilization (between 25% and 50%), orange colour; Q4 - low utilization (less than 25%), red colour. In addition, each marker holds a number representing the degree of facility utilization and encapsulates a more detailed information about facility name, utilization and area, as it is shown on the example of Cultural Centre Marfa (B).

In addition, the inventory contains information about type of service or services that are offered in each facility together with their quantitative characteristic. This characteristic is used for the purpose of service compatibility analysis in two ways. First of all, in case of MSF, it is used for evaluation of services already combined and offered together. The evaluation aims to determine whether this combination is favourable or not. Furthermore, service compatibility analysis is also conducted to verify whether additional service that is planning to be introduced fits the one that is being offered already. Regardless the case, relationships between services are represented graphically to facilitate interpretation. Figure 8 depicts compatibility analysis conducted to evaluate two municipal services from Girona offered in the same facility: Service of City Historical Archive and Service of Image Research and Dissemination. The distance between each characteristic of two services has been calculated and represented graphically. All characteristics aim to compare services from different perspectives. However, the type and number of characteristics is flexible and can be adjusted if necessary. On the presented example, services are fully compatible in three aspects: scope - reflecting that both services are dedicated to all city inhabitants and not only the neighbourhood; affiliation – telling that services are managed by the same administrative department; and delivery, indicating back office/front office balance. In addition, evaluated services turned out to be almost fully compatible in the nature aspect which reflect how service is categorized by its users (e.g. social, educational, cultural, etc.). Moreover, users of both services are very alike considering their age (85%). Similarly, services are very analogous considering their stakeholders - all people that are interested or involved in service provision (80%). Finally, the presence characteristic uncovers the lowest (although still high – 75%) compatibility indicating whether user in person presence is required to deliver the service or it can be accomplished virtually. Hence, the closer the value to 100%, the more compatible the services are; and the closer the value to 0%, the less compatible the services are. High compatibility value is an indication of beneficial service combination, while low compatibility value indicates services which combination should be avoided. The collection of all types of relationships between services represented on the radar chart is more convenient for decision making since it does not only provide a total compatibility value, but also helps to understand why.

Decision making

The framework helps in obtaining SA on spatial resources and indicates possible service combinations; however, it does not make decisions by itself. The final decision has to be taken by decision maker - a human being. This responsible professional shall analyse the results and combine them with his experience, human judgment and other intangible factors such as policies and urban planning acts to take the appropriate decision.

Decision making process has three objectives. The first one is to increase the facility economic efficiency by maximizing space-use. Another one is to improve service quality by enhancing space accordingly to the needs. The last objective is to increase general performance by reorganizing services in the meaningful way.

Maximizing space-use

Maximizing space-use may be the objective of decision-making in case of facilities with low space utilization rate. The space surplus can be leased to the private sector creating new source of income. It may also be allocated for numerous purposes depending on current needs: it can be utilized for introducing additional and compatible services improving the offer of services and increasing the value added; it could be leased to the non-governmental organizations for the development of their activities or given for social purposes of the local community to make the environment more vibrant.

Surface enhancement for service improvement

Surface enhancement may be necessary if space scarcity has been detected during the space-use analysis. Surface enhancement aims to assure appropriate spatial conditions for services that require more space to develop their activities. In such cases finding larger facility for the service should be considered. This however could be difficult and may render additional cost or new facility construction. The compromise may be achieved by moving a part of service (a subservice or activity) to another location in the way that makes the inconvenience minimal. This decision however has to be considered individually for every case.

Service rearrangement

Service rearrangement may be required if the degree of service compatibility is relatively low. Services offered together in one facility that are not related to each other waste the potential that can be rendered when well-matched, compatible services are combined. A fortunate combination of services creates collaborations, safes resources and citizen´s time thanks to shared uses. For this reason, service compatibility analysis should be considered during the decision making process whenever various services or activities are carried out simultaneously under one roof.

Conclusions and future research

Changing environment causes discrepancies between space needed for provision of public services and the amount of space available in public facilities leading to space overuse or underuse. This situation may affect service quality if the space is overused, or cause waste of resources in case of underused spaces. In order to mitigate the effects of this unfavourable situation, the framework for space-use efficiency and arrangement of public services aims for enhancement of functional and economic efficiency in public buildings.

The framework is a decision-support tool providing situational awareness on space-use on multiple public buildings of different types. It identifies underutilized buildings and recommends how combine compatible services, converting traditional single service facilities into multi service facilities.

The framework`s underlying assumption is a logical separation of service form facility where it is offered. Service and facility are evaluated separately, but the results are contrasted posteriorly. It consists of four key components: space-use analysis, service-compatibility analysis, space-use inventory and decision making. Each of these elements has been explained in details end exemplified:

- Space-use analysis evaluated service space demand and contrasted it with space supply to disclose either space scarcity, conformity or excess.
- Service-compatibility analysis describes services quantitatively in different aspects and calculates the distance between them to indicate how close they are to each other.
- Space-use inventory contains results of space-use analysis and compatibility analysis performed on various facilities.
- Decision making is supported by the results of the space-use inventory (situational awareness) and may has one of the three objectives depending on the situation: maximize space-use, space enhancement to improve the service conditions, or service rearrangement.

This paper contributes to the state of the art by:

1. Joint approach for optimization of public services and facilities, which used to be considered either separately, or in the fixed relation (type of service determines the type of facility, e.g. school), preventing a more efficient use of space.
2. Encouraging beneficial organization of public services not by proposing new facility but instead, by taking advantage and repurposing already existing space resources, making it more affordable (low-cost) and reducing a negative environmental impact (space-use is strongly related with use of water and electricity).
3. Proposing the framework which encompasses two decisive processes: space-use analysis and service compatibility analysis. Herewith, the paper contributes to the facility planning and service programming by filling the gap between facility location problem, on the one side, and facility layout as well as scheduling problem on the other.

The focus of this paper was stressed on the space-use aspect and compatibility of public services. However, the possibilities of public facilities and services performance improvement are much broader. Therefore, the authors postulate that the framework application shall go in parallel with other e-government initiatives, in particular the process of public services virtualization. There are many services that do not require citizen´s presence and may be entirely accomplished online.

Much research also remains to determine the citizens' sentiments related to the interaction with public services. Application of opinion mining tools would allow a better understanding of citizen´s needs and therefore provide the opportunity to take them into consideration in future adjustments. In addition, discovering the patterns of the interaction of the citizenry with the public services using of crowd sensing techniques would provide the opportunity to anticipate the citizen's behaviour and organize space and services in the user-friendly way.

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List of tables

Table 1. Comparison of space supply and space demand on the example of research facility.

Types of Spaces	Space supply	Activity	Number of users	APPF (m^2)	Space demand (m^2)	Supply-demand (m^2)
Research lab	930.8	Research	64	5.6	358.4	572.4
Professors' office	855.3	Professors' activity	84	11.2	936.6	-81.3
IT workshop	44.65	IT infr. maintenance	4	11.2	44.6	0.05
Admin. office	149.45	Administration	12	9.3	111.6	37.9
TOTAL:	1980.2				1451.2	529
Utilization rate:						73%

Table 2. Values of attributes of User characteristic for Service 1 and Service 2.

FEATURE:	User			
ATTRIBUTES:	Children	Youth	Adults	Elderly
Service 1	32%	50%	10%	8%
Service 2	25%	25%	25%	25%

Fig 1

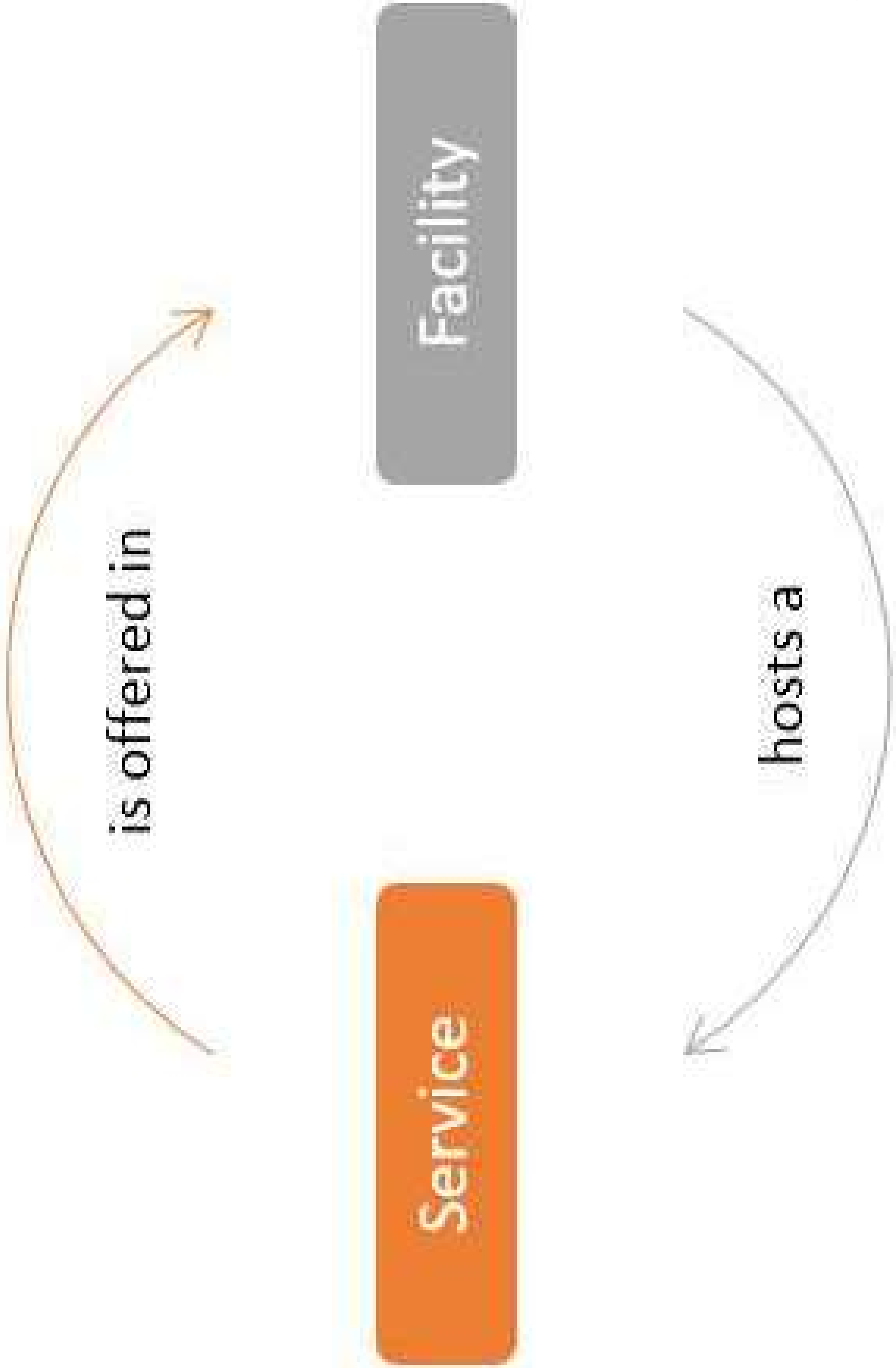

Fig 2

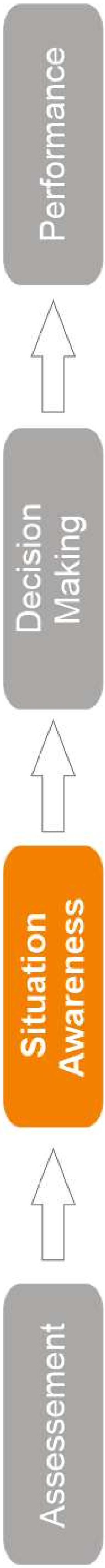
Performance
Decision Making
Situation Awareness
Assessement

Fig 3

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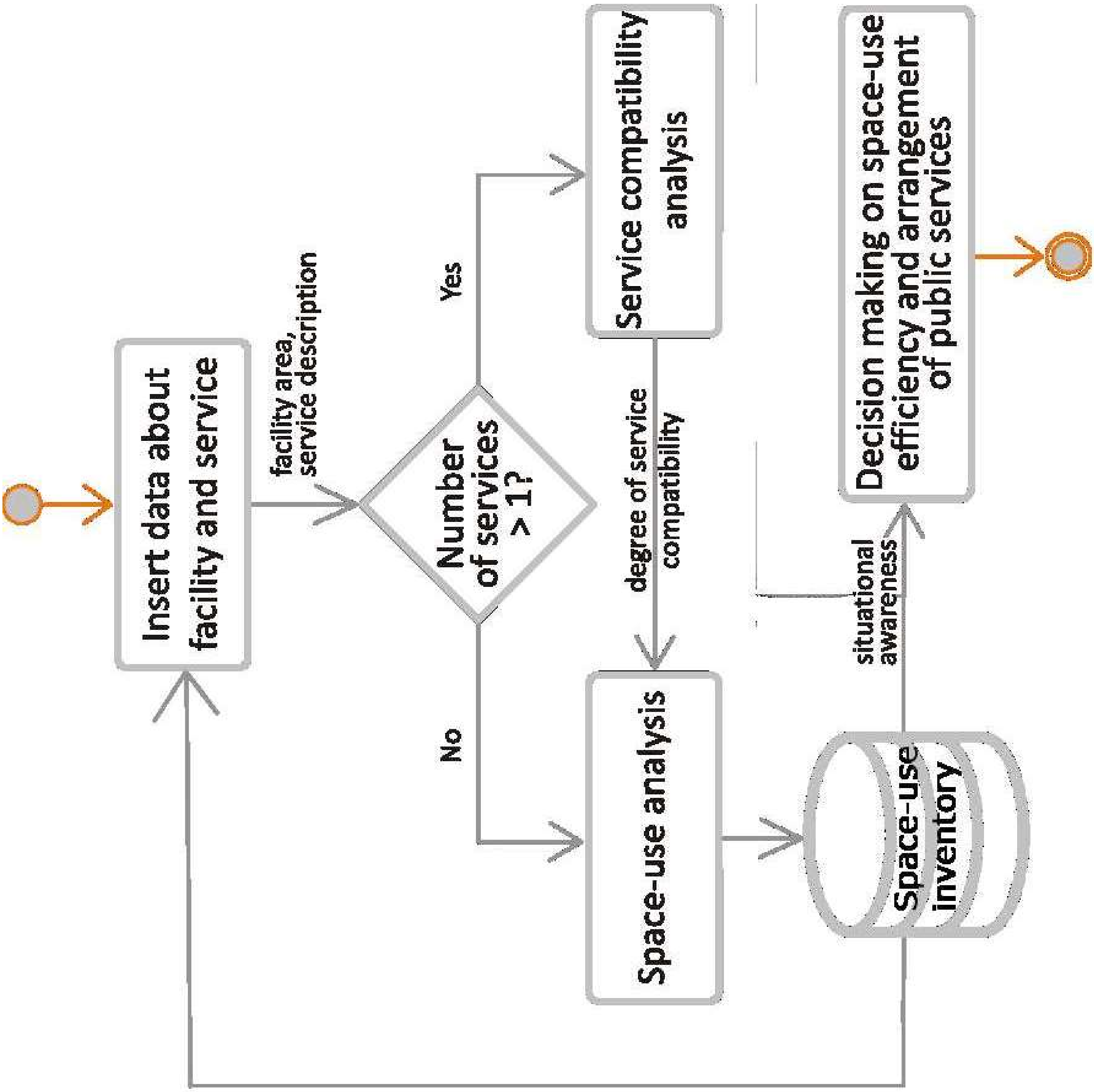

Fig 4

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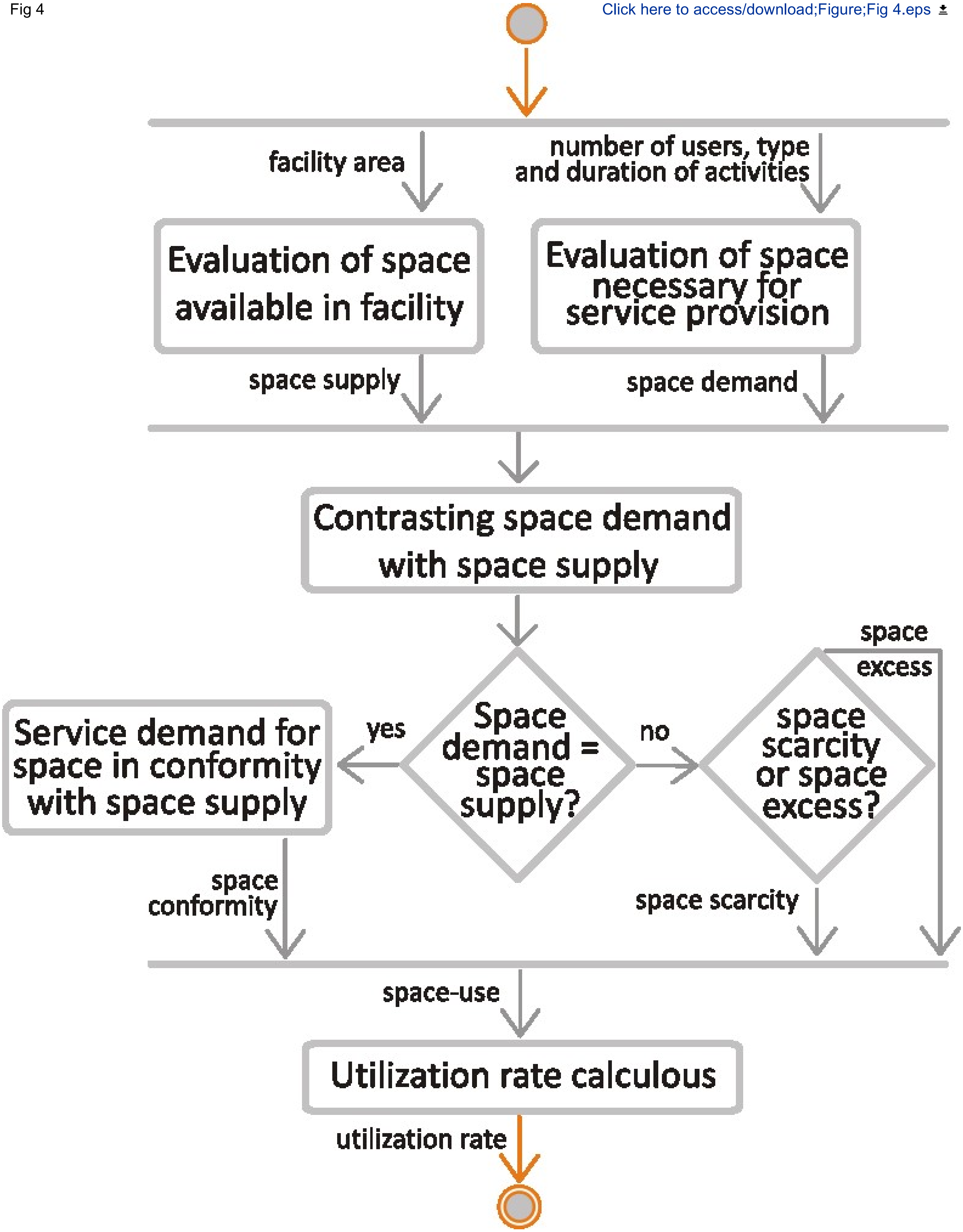
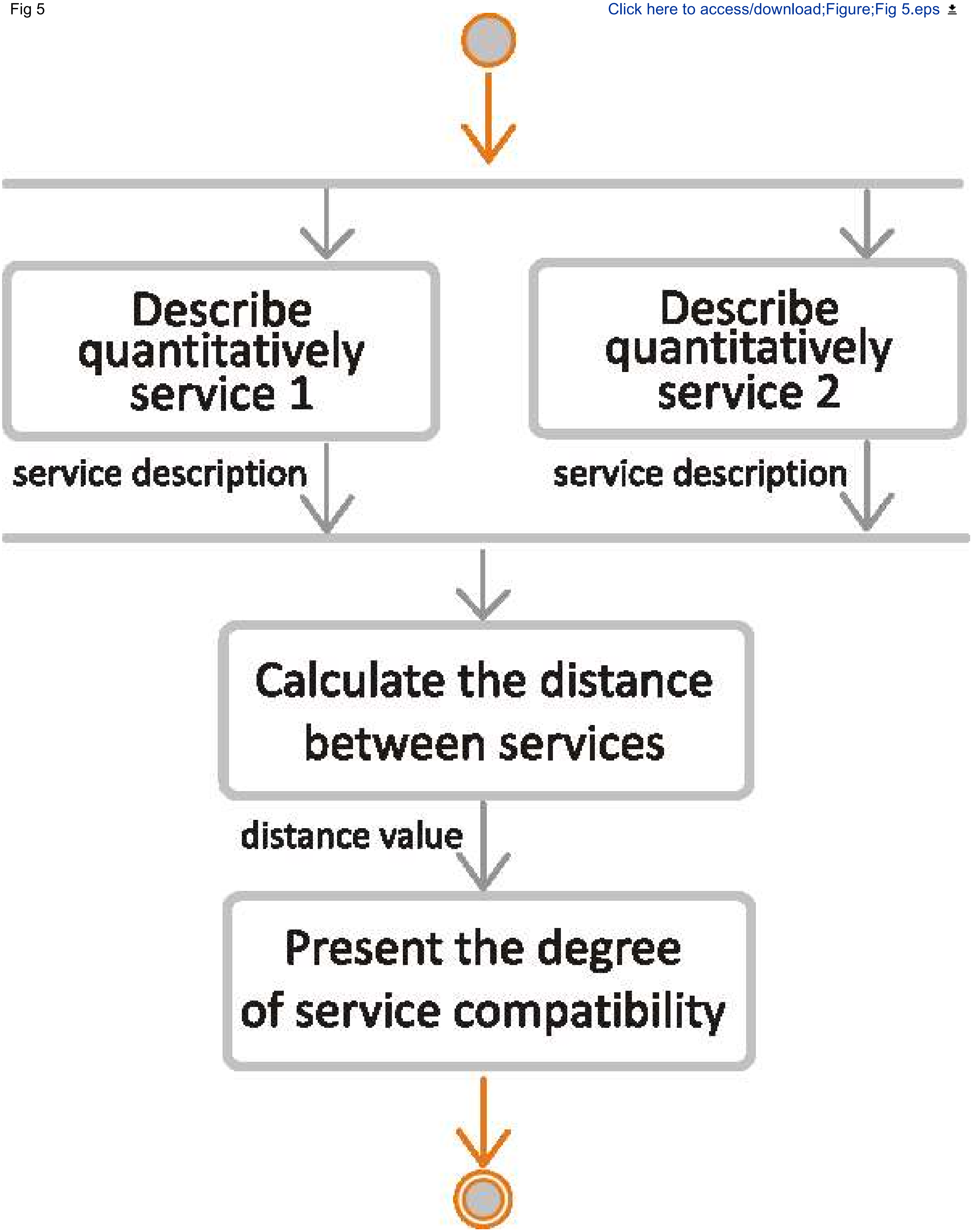


Fig 5



Describe quantitatively service 1
Describe quantitatively service 2
service description
service description
Calculate the distance between services
distance value
Present the degree of service compatibility

Fig 6

	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 Center Service "Sant Narcís"	15. Municipal Market Service	16. Youth Center Service "Els Químics"	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
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

Fig 7

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Fig 8

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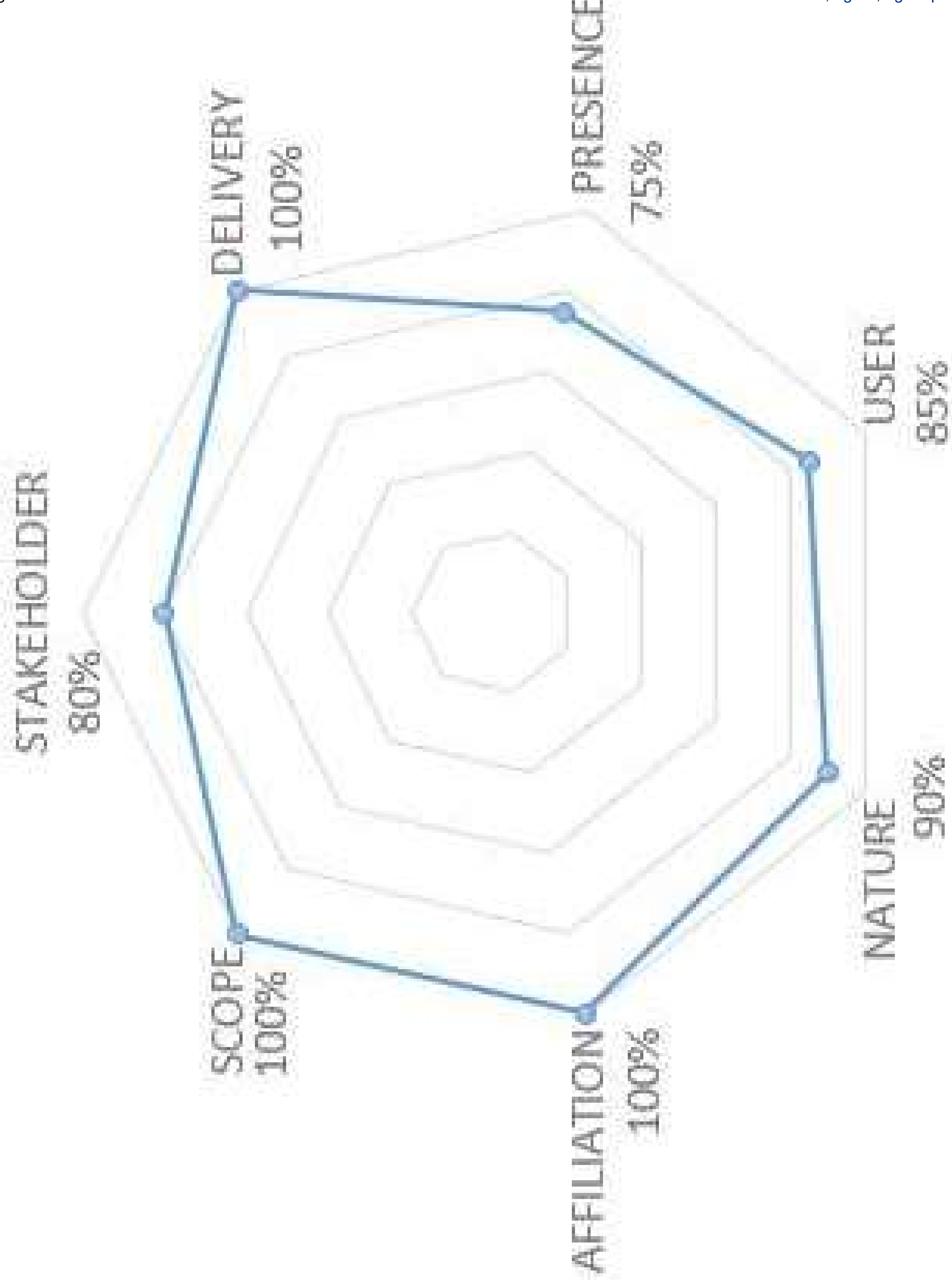

Fig 1. Relationship between service and facility.

Fig 2. Situation awareness in the context of decision making. (Adapted from Endsley & Garland, 2000).

Fig 3. A high-level overview of the decision support framework for space-use efficiency and arrangement of public services.

Fig 4. Process of space-use analysis.

Fig 5. An overview of the process of service compatibility definition.

Fig 6. Compatibility matrix of 30 services. All values in %. Source: Rusek et al., 2016.

Fig 7. Space-use inventory: spatial representation of public facilities with information about space utilization using Google Maps API.

Fig 8. Compatibility relationships between Service of City Historical Archive and Service of Image Research and Dissemination.