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Towards a segmentation of science parks: A typology study on science parks in Europe☆

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A B S T R A C T

Although science parks are established globally for decades as an innovation policy instrument to foster growth and networking, there is limited attention given towards research into possible types within these real estate objects. Prior attempts in categorising science parks are characterised by the limited number of cases and/or variables. Science parks are believed to enhance innovation, entrepreneurship, and economic value for firms and regions. Past academic research showed mixed results on these performances and it is reasoned that distinct types within science parks exist that might explain these unclear results. We argue that before we can grasp what science parks can do, we should know what they are. Therefore, a survey on science park characteristics was completed by 82 science park managers in Europe. A cluster analysis was conducted which grouped the 82 participating science parks in three types; 'research', 'cooperative', and 'incubator' locations. Next, differences and similarities of these three types within science parks in Europe were analysed as a basis for advancing the academic debate. The types provide further understanding of science parks and offer researchers, practitioners, and policy-makers a means to compare, market, and benchmark science parks more adequately.

1. Introduction

Among innovation policies, science parks (hereafter: SPs) belong to the traditional supply-side instruments that facilitate networking among actors (Edler and Georghiou, 2007). SPs have existed since the 1950s and have gained increasing attention from academia since the 1990s in regard to their impact (Albahari et al., 2010). According to Link and Scott (2015) a SP is set up as a public-private partnership and the current definition by IASP which is most often used by academia is: "…an organisation managed by specialised professionals, whose main aim is to increase the wealth of its community by promoting the culture of innovation and the competitiveness of its associated businesses and knowledge-based institutions. To enable these goals to be met, a Science Park stimulates and manages the flow of knowledge and technology amongst universities, R&D institutions, companies and markets; it facilitates the creation and growth of innovation-based companies through incubation and spin-off processes; and provides other value-added services together with high quality space and facilities" (IASP, 2017). However, Hansson et al. (2005) stated that due to the broadness and wide application a universal accepted definition has not been decided on.

Many different terms, such as *research park*, *innovation centre, hi-tech park*, *science & technology park* have been used interchangeably in prior SP studies (Chan and Lau, 2005; Vásquez-Urriago et al., 2016). It seems that the popularity of the terminology is country-specific, such as *research park* in the United States, *SP* in Europe, *technology park* in Asia (Link and Scott, 2015), *campus* in the Netherlands (Hoeger and Christiaanse, 2007; Boekholt et al., 2009), and *technopole* in the Francophone world (Massey et al., 1992; 5). Also, initiators of SPs may vary from governments, regions, universities, high-tech firms to investors or developers with each having different goals (Saublens, 2007). In the past there have been attempts to characterise SP types. Link and Link (2003) concluded that there are mainly three categories of SPs in the U.S.; real estate parks with no university affiliation; and university research parks with and without tenant selection criteria. Other studies have chosen different criteria. For example, Escorsa and Valls (1996) proposed SP segmentation either by regional policy on technology transfer or SP activity. Zhang (2002) used knowledge intensiveness and size in relation to other real estate properties and Hoeger and Christiaanse (2007) applied a spatial segmentation (e.g. inner city-campuses and greenfield campuses) and a functional segmentation (e.g. high-tech campuses, and corporate campuses). As a result of different dimensions of SPs studied so far, these prior studies seem insufficient for recognising SP types. Moreover, the focal objective of these past

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studies was not the identification of sound and different types. To do so, a more extensive list of defining characteristics should be used.

Therefore the main research question of this paper is: *what are the main characteristics of SPs and which SP types can be distinguished?*

The need for a comprehensive SP classification is manifold. In general, a classification or segmentation makes advanced conceptualisation, reasoning, and data analysis possible (Bailey, 1994). It serves as a means to distinguish SPs from other property-based initiatives such as business and light-industrial parks (Shearmur and Doloreux, 2000) and as an explanation of growth differences in number of firms and employees (Link and Link, 2003). Current SP assessment literature does not acknowledge differences in structures, aims, and functions (e.g. Siegel et al., 2003a; Capello and Morrison, 2009).

From a policy perspective, SP development involves risk and capital and it is therefore essential not to take one generic SP model for granted, but further investigate the SP concept for better decision-making (Morlacchi and Martin, 2009). Also, because a clear and shared segmentation of SPs is absent, discussion on SP performance remains difficult (National Research Council, 2009; Ferrara et al., 2015). Although some specific SP cases prove to be effective in enhancing the performance of tenants, the conditions that result in successful SPs remain unexplored (Yang et al., 2009). The exploration of possible distinct types is needed from a policy perspective as various regions have different objectives and therefore require different policy implementation. A segmentation therefore advances the debate regarding firm benefits as a result of different SP models (Siegel et al., 2003b; Saublens, 2007; Capello and Morrison, 2009), and it makes evaluation of SP performance less complex (Lamperti et al., 2017). Empirical proof of different SP schemes could also provide practitioners with useful insight in the adequate design, development, operation, and evaluation of SPs.

This paper adopts an empirical and inductive approach towards the SP context in Europe with limited emphasis on theory, which is in line with research on science technology innovation policy focussing on a specific policy measure (Morlacchi and Martin, 2009). The aim of this study is to come to an empirical conceptualisation of SP types based on their distinguishing characteristics in practice.

To answer the research question, first relevant SP characteristics from prior research are inventoried (literature review Section 2). Then data is collected on SP characteristics through a survey among European SP managers (Section 3) and a cluster analysis is performed based on the (dis)similar SP characteristics to produce a segmentation (Section 4). Lastly in Section 5, conclusions, limitation and directions for future research are considered.

2. Literature review

Previous empiric research on firm performance yielded mixed results of SP impact (Squicciarini, 2008; Albahari et al., 2010; Vásquez-Urriago et al., 2016; Ramírez-Alesón and Fernández-Olmos, 2017). Also, it focused largely on comparing performances in terms of economic growth, innovation or collaboration between on and off park firms (e.g. Löfsten and Lindelöf, 2002; Siegel et al., 2003a; Dettwiler et al., 2006; Squicciarini, 2008; Lamperti et al., 2017; Ramírez-Alesón and Fernández-Olmos, 2017). Such, comparative studies often focus solely on the outcome and the explanation of these results, while less attention is given to the characteristics of the SP these firms were located at and the effect of heterogeneity among SP types (Ramírez-Alesón and Fernández-Olmos, 2017). In order to seek significantly different types and to improve the quality of a segmentation it is important to identify key characteristics of the object of interest (Bailey, 1994). In this subsection several key characteristics from literature are discussed which will be used as input for a segmentation of SPs, which are grouped in four themes. Following Zhang (2002) *knowledge intensiveness* and *size* are discussed, while *organisation* and *location* aspects of SPs are added to gain more insight on SP characteristics. Within the following subsections a table is included with the relevant characteristics per theme.

2.1. Knowledge intensiveness

The role of the university/higher educational institution (HEI) is signified as a provider of facilities, services and knowledge for firms at SPs (Löfsten and Lindelöf, 2002). On the other hand, the university could also benefit from the link with a SP, such as increasing publication and patenting activities, more options to acquire skilled scientists and extramural funding (National Research Council, 2009; 16). Moreover, SPs provide short, medium, and long-term accommodation for firms in different maturity stages (IASP, 2017). Specifically, SPs are of interest to start-ups, small-medium enterprises (SME), large firms, and well-established multinationals alike (Hansson et al., 2005). SPs can focus on attracting firms from one or more target industries (Squicciarini, 2008; Lamperti et al., 2017; Van Winden and Carvalho, 2015). Liberati et al. (2016) grouped SPs in three groups: (1) general with many sectors covered, (2) mixed with neither high nor low sectors, and (3) specialised with a strong focus on a few sectors. This characteristic can split SPs in two groups focussing either on just high-technology firms or on firms with a focus on a specific technology or sector (e.g. biotechnology, information technologies, semiconductors, etc.) (Boekholt et al., 2009). Close proximity of firms forming a mix of industries can provide for synergy and innovation from previously unrelated disciplines (Van Winden and Carvalho, 2015), and a broad search profile of industries can minimise vacancy on SPs (Shearmur and Doloreux, 2000). In Table 1 the four SP characteristics regarding knowledge intensiveness are listed.

2.2. Size

The style of a SP has been suggested by Zhang (2002) to be one of the distinguishing characteristics; small – centre/incubator with a high

Table 1
SP characteristics: *knowledge intensiveness.*

Name	Levels	Source
HEI (dichotomous)	Presence of a university and/or other higher educational institutions (HEI).	(Löfsten and Lindelöf, 2002; Link and Link, 2003; Albahari et al., 2013b)
Research institutes (dichotomous)	Presence of a public (non-educational) and/or private research institutes.	(Capello and Morrison, 2009; Lamperti et al., 2017)
SME and/or multinational corporations (dichotomous)	Presence of small medium enterprises and/or multinational corporations.	(Hansson et al., 2005; National Research Council, 2009)
Technology sector group (categorical)	Resident organisations are active in (1) Air, space, and land transportation technologies, (2) Agricultural, mineralogy, and metrology technologies, (3) Computer, communications, and internet technologies, (4) Electronics and automation, (5) Energy-related technologies, (6) Industrial, (7) Medical, health, and chemistry, and (8) No specific sector group.	(WAINOVA, 2009; Sanz and Monasterio, 2012)

Table 2
SP characteristics: *size.*

Name	Levels	Source
Surface area site (continuous)	Surface of the site measured in square metres	(Zhang, 2002)
Single or multiple buildings (dichotomous)	Single building locations or multi-building locations (park-style)	(Zhang, 2002; European Commission, 2013)
Number of resident organisations (categorical)	(1) Less than 50, (2) between 50 and 100, (3) between 100 and 200, (4) between 200 and 400, (5) between 400 and 600, (6) between 600 and 1000, or (7) more than 1000	(Link and Link, 2003)

building density, medium – park/campus with a low building density, and large – with the SP as a city/region. It follows, that these SP styles are related to the total surface area, number of organisations, and facilities and services that the SP can provide. Generally, the mix of buildings on SPs include, multi-tenant buildings (including incubators specifically aimed at start-ups), collaboration spaces, single-tenant buildings and empty plots for future development by tenants (European Commission, 2013). Link and Link (2003) found university-owned SPs grow significantly less in the number of companies and employees, signifying that these real estate parks are more focused on real estate development. Moreover, in their research, SP size was argued by SP directors to be related to success factors such as profitability, regional economic contribution, and the ability to interact with universities. Size characteristics are expressed in surface area, number of buildings and number of resident organisations (Table 2).

2.3. Organisation

SPs have existed and evolved through the decades from early university-initiates to joint partnerships between university, industry and governments (i.e. triple helix) (Annerstedt, 2006). Massey et al. (1992) and Albahari et al. (2013b) distinguished technology parks and SPs on the lack of formal relationships or shareholding with a university, which shows that SP ownership is one of their distinguishing characteristics. Furthermore, other ownership models include public, private, university-public, triple helix, university-private, and public-private models with not one prevailing model (Dabrowska, 2016). As a result of the nature of these organisations, they will have different objectives and priorities for the SP. These goals can be partly met through, if present, the SP management function, which varies from an informal team, single manager or a designated company (Westhead and Batstone, 1999; Siegel et al., 2003a). Besides maintaining the park, its facilities and services, an important task for SP management is promoting networking in- and outside the park and enhancing community building on-park (Capello and Morrison, 2009; Van Winden and Carvalho, 2015). The long history of SPs has resulted in some research into the age of SPs. Link and Link (2003) found that incubators were less likely to be present at older American SPs. Younger Finnish SPs were more focused on a few technology sectors than their older counterparts (Squicciarini, 2008). While Lamperti et al. (2017) found that firm growth and innovative output of tenants on older Italian SPs was lower, which could be explained through the recent policy interest and funding towards SPs in Italy. For this theme ownership structure, management function and age of the SP are listed in Table 3.

2.4. Location

The urban context of SPs can be viewed as the relation between SP and city which can be distinguished in five ways; (1) city as the SP, (2) city contains the SP, (3) city overlaps with the SP, (4) city touches the SP, and (5) city is disjointed from SP (Curvelo Magdaniel et al., 2018). Recently there has been a shift from suburban to urban areas for high tech development and human talent (Florida, 2014). Lamperti et al. (2017) proposed that a SP should at least accommodate one incubator or research institution. Besides that, the main offering of a SP is its facilities and services. Facilities can consist of “low tech” facilities, such as meeting rooms, cleaning and security, business plan support, etc. and “high tech” facilities like laboratories, exhibition and piloting space, showrooms, and clean rooms, etc. (Van Winden and Carvalho, 2015). Similarly, Van der Borgh et al. (2012) distinguished between “technical complementarities” (e.g. clean rooms, laboratories) and “non-technical complementarities” (e.g. office space, conference rooms, restaurants, sport facilities). Other authors suggested that SPs should also provide firms with services that support their research activities (Lamperti et al., 2017). Leisure facilities (e.g. sport facilities) can lead to positive moods on employee level, which enhance creative problem solving and general performance (Brief and Weiss, 2002). Support services can vary between administrative, managerial and technological support (Saublens, 2007). The access to financial aid is suggested by Van de Klundert and Van Winden (2008) as one of the features of the economic base surrounding a SP. This financial aid can involve seed capital and/or venture capital, which are the financial support by venture capitalist funds for respectively the creation and growth of businesses (Etzkowitz et al., 2009). One of the features of certain SPs, often the incubator, is the shared use of facilities to reduce costs for tenant firms and contribute to knowledge transfer through interaction (Dettwiler et al., 2006). Aside from cost reduction, sharing expensive equipment gives small firms the means to use advanced facilities that they otherwise cannot afford (Van de Klundert and Van Winden, 2008). The large range of facilities and services that SPs provide, enable especially

Table 3
SP characteristics: *organisation.*

	Levels	Source
Ownership structure (categorical)	SP ownership; university, public, private, university-public, triple helix (partnership between university-government-industry), university-private, or public-private	(Siegel et al., 2003a; Albahari et al., 2013b; Dabrowska, 2016)
Management function (categorical)	(1) There is no management function of any kind (informal or formal), (2) informal teams (there is no explicitly assigned organising management), (3) single on-site manager, or (4) on-site management company	(Westhead and Batstone, 1999; Zhang, 2002; Siegel et al., 2003b; IASP, 2017)
Age of SP (continuous)	Years since establishment of the SP	(Link and Link, 2003; Squicciarini, 2008; Lamperti et al., 2017)

Table 4
SP characteristics: *location.*

Name	Levels	Source
Urban context (categorical)	(1) City contains the location (there are no clear boundaries between the SP and the urban fabric), (2) location overlaps the city (on some areas the SP is integrated within the city), (3) location touches the city (the SP and the city is bounded by for instance a highway), (4) location is disjointed from the city (the SP is completely detached from the urban fabric), or (5) the SP is located on multiple locations (with clear distinction between SPs)	(Curvelo Magdaniel et al., 2018)
Presence of work-related facilities (dichotomous)	Auditoriums, conference rooms, eating facilities (e.g. canteen, restaurants), exhibition rooms or showroom areas, libraries, and meeting rooms	(WAINOVA, 2009; Sanz and Monasterio, 2012)
Presence of leisure facilities (dichotomous)	Cinemas, hotels, sport centres, and sports grounds	(WAINOVA, 2009; Sanz and Monasterio, 2012)
Presence of other facilities (dichotomous)	Banking, child care, cleaning and maintenance, medical (e.g. general practitioners, pharmacy), residential housing, safety and security, shop (food), shop (non-food), and travel agency	(WAINOVA, 2009; Sanz and Monasterio, 2012)
Presence of services (dichotomous)	Accounting, administrative services, consultancy, graphical design, information access, management support, marketing, hosting networking events, training, and venture capital access	(WAINOVA, 2009; Ratinho and Henriques, 2010; Sanz and Monasterio, 2012)
Presence and shared usage of R&D facilities space (categorical)	Presence of laboratory, incubator, clean room, and pilot room spaces and whether it is designated for shared usage for users from different resident organisations	(e.g. Van der Borgh et al., 2012; Lamperti et al., 2017)
Presence of manufacturing space (dichotomous)	Spaces designated for manufacturing purposes	(Link and Link, 2003)

smaller firms to focus on their core activities (Aaboen, 2009; Dabrowska, 2016). In Table 4 the ten location characteristics are found.

3. Methods

3.1. Participants

The various SP characteristics of the four themes formed the input for a web survey consisting of 25 English questions for European SP managers or representatives. A survey was chosen above desk research or interviews, because in general archival data is incomplete, interviews are more time consuming, and the goal was to collect data on as many SP as possible. The survey aimed to reveal the (dis)similarities among characteristics of cases. It was hosted online from December 2016 until March 2017.

The total population of operational SPs was attained through several online sources, such as from prior reports, member lists of (inter)national SP associations, and SP references in empiric literature. Through cross-referencing among (inter)national lists and references made by the authors a long list was produced of European SPs. Cases derived from international sources include the Atlas of Innovation compiled by the World Alliance for Innovation, which was a list of science, technology parks and innovation-based incubators around the world (WAINOVA, 2009), and the current member list of the IASP. In addition, member lists of national SP associations in Europe were examined. By no means was this attempt conclusive for finding all SPs in Europe. This method provided for a substantial list of 675 SP locations across 27 countries in Europe. The list of European SPs formed the total population of this study. SP representatives of all 675 locations were contacted through an initial email with a link to the web survey with three follow-up reminders.

3.2. Method of cluster analysis

The categorical variable 'technology sector groups' was recoded into 'focus of technology sector groups', a categorical variable with four values; 'uniform focus' (one sector group), 'high focus' (2 or 3 sector groups), 'medium focus' (4 sector groups), and 'low focus' (0 or 5 or more sector groups). This follows Squicciarini (2008) and Liberati et al. (2016) in order to compare cases on the technology sectors covered. Furthermore, dichotomous variables regarding facilities/services indicating presence of a certain amenity were recoded to the variables 'mix of (work-related/leisure/other) facilities and services'. This variable is considered ordinal, because it is limited to the different types of facilities and services, and does not reveal the quantity of each type.

The SP characteristics i.e. proposed clustering variables were measured on different scales: continuous (e.g. surface area); ordinal (e.g. mix of facilities), and nominal (e.g. shared usage of R&D facilities) or dichotomous (presence variables). This made techniques, such as hierarchical clustering and k-means clustering problematic as the mathematical distance between continuous, ordinal, or dichotomous variables are calculated through Euclidean distance or matching measures between variables with similar measurement levels. Therefore, the analysis of (dis)similarities among variables was conducted through the Twostep clustering technique from SPSS Version 23, as this technique can handle both continuous and categorical variables simultaneously and the procedure searches for the optimal number of clusters, which makes this technique more suitable than k-means or hierarchical clustering for the present data (Norušis, 2011). As the name suggests the two-step procedure follows two phases; preclustering and clustering. In the initial phase, cases are merged within preclusters based on log-likelihood distance measures. In the second phase, the preclusters are grouped in an optimal number of clusters based on either the Schwarz Bayesian Criterion (BIC) or the Akaike information criterion (AIC). In the auto-clustering phase, the BIC/AIC and the ratio between clusters are (amongst others) calculated. A lower BIC/AIC value is preferred for a better fitting model, whereas in contrast the distance measure is preferably higher as it indicates the dissimilarity of clusters.

This technique is often used to create market segments of people or objects (Mooi and Sarstedt, 2014). But, the application of cluster analysis has also been used for clustering at various real estate levels, such as buildings (Pan and Li, 2015) and neighbourhoods (Trudeau, 2013).

The Twostep algorithm provides a "goodness" of the resulting clustering solution through the so-called "cohesiveness" of the solution, ranging from -1 to $+1$. This cluster quality is based on the similarity of cases within clusters and differences among clusters. Values between -1 and 0.2 indicate poor cluster quality, between 0.2 and 0.5 is considered fair and above 0.5 good. In addition, the algorithm shows for each variable their importance for predicting cluster formation, which ranges from 0 (no effect) to 1 (very important) (Mooi and Sarstedt, 2014). Although variables with predictor values of 0.02 or lower can be considered, this will result in similar values of variables among cases (Tkaczynski, 2017). For the purpose of distinguishing different clusters between cases it is useful to select variables with relatively high predictor values.

Table 5
Number of SPs per country.

Country	Total	Response	Country	Total	Response
Northern Europe	***248***	***30***	***Southern Europe***	***151***	***18***
Denmark	8	4	Greece	6	0
Estonia	4	1	Italy	59	6
Finland	48	0	Portugal	16	4
Iceland	1	1	Slovenia	1	1
Ireland	2	0	Spain	69	7
Latvia	3	0	***Western Europe***	***221***	***32***
Lithuania	3	0	Austria	5	2
Norway	34	4	Belgium	8	0
Sweden	32	6	France	51	4
United Kingdom	113	14	Germany	110	5
Eastern Europe	***55***	***2***	Luxembourg	2	0
Bulgaria	3	0	The Netherlands	35	15
Czech Republic	40	0	Switzerland	10	6
Poland	8	1			
Romania	1	0			
Slovakia	3	1			

4. Results

First the inventory of the SP population and sample in Europe are discussed. Furthermore, the selection of clustering variables and cluster solutions are discussed. Additional tests of differences are presented to further explore these solutions. Finally, the results are compared with findings of previous literature.

4.1. SPs sample

Table 5 shows the total population among 27 countries and the respective response of 82 SPs.

Based on the United Nations segmentation into north, east, south, and west Europe, the sample of SPs used in this study is representative for the SP population as a whole, as no significant differences were found between the regional distribution of the SP population and the SPs within the sample with $\chi^2(3) = 4.28$ $p = .23$. Table 5 shows that within the SP sample only Eastern European countries are under-represented. Even after multiple reminders, the response rate was only 12%, which was possibly caused by the vast amount of emails that SP management receives daily. Moreover, the relatively higher response rates of Northern, Southern and Western European countries was probably due to respondents having a higher English proficiency (European Commission, 2012).

4.2. Selection of clustering variables

For cluster analysis Formann (1984) suggested a minimum sample size equal to 2^m, where m is the number of clustering variables. Factor analysis as a means to reduce the number of continuous variables into components was considered but rejected for the present analysis. Firstly, the correlations among those variables are relatively low with less than half of the possible relations exhibiting a correlation between .3 and .592 (Tabachnick and Fidell, 2001). Secondly, the Kaiser's measure of sampling adequacy values are mediocre at best (Mooi and Sarstedt, 2014). With $2^m = N$, seven of the 20 clustering variables could be used simultaneously for the cluster analysis for a sample of 82. Frequencies for each of the 20 variables, categorised per theme can be found in the appendices A–D.

The selection of clustering variables was based on three criteria; (1) cover the four themes; 'knowledge intensiveness', 'size', 'organisation', and 'location', (2) a silhouette coefficient of at least .3, which indicated a degree of cluster cohesion, and (3) predictor values for cluster membership were at least 0.02. Through numerous clustering attempts an overview of different cluster solutions were computed. In Appendix E predictor values are listed for cluster memberships of 22 auto-clustered solutions.

The seven variables[1] selected for clustering were; *presence of HEI, presence of research institutes, surface area site, ownership structure, mix of leisure facilities, mix of other facilities,* and *laboratory*. Among the 22 auto-clustered results, cluster solution 1 with the seven variables covered all four themes, was sufficiently cohesive, and the lowest predictor values of its variants were relative high compared to other cohesive solutions. Correlations between these clustering variables were relatively low with none exceeding .6 and therefore posed no issues of multicollinearity (Mooi and Sarstedt, 2014). The seven preselected variables and the resulting cluster solutions will be discussed in the following subsection.

4.3. Cluster solutions

Initial autoclustering of the Twostep cluster analysis with the BIC produced a 2-cluster solution with a silhouette coefficient of .4. Appendix F shows the 2-cluster solution selected by the algorithm, because it had the lowest BIC value (1304,481) and highest ratio of distance measure (1,610), indicating significant different subclusters. In the case of the AIC the 5-cluster solution was selected (1062,005) as the lowest AIC value paired with the highest ratio of distance measure (1,513). Further investigation of the predictor importance showed that the variables *presence of research institutes* and *presence of HEI* dictated cluster membership to a large extent (respectively 1.0 and 0.95, the other five variables ranged between 0.25 and 0.09). This suggested that a 2-cluster solution was not optimal, because it largely divided the sample in two groups, one with both types of organisations and one group without. Turning to the 5-cluster solution, the predictor importance of each variable was more evenly distributed compared to the previous 2-cluster solution. The two most important predictors were *laboratory* (1.0) and *presence of research institutes* (0.83) with the predictor values of the other five variables varying between 0.65 and 0.26.

Ultimately, the 3-cluster solution was selected for further analysis as the ratio of distance measure was relatively high (1,296) and the silhouette coefficient compared to the 5-cluster solution was higher. Moreover, in Appendix G cluster membership is compared on case-level between the 3 and 5-cluster solutions, which revealed that one cluster was almost identical in both solutions, while the other two clusters in the 3-cluster solution were divided among four clusters in the 5-cluster solution. For practical reasons, dividing the sample of 82 cases into 5 groups resulted in relatively small clusters.

To describe the results, in Table 6 the first five columns show the cluster variables, the number of cases, percentages, mode/mean and standard deviation respectively. In the remaining columns the three cluster solutions are listed with their counts per value, percentage in relation to cluster size for categorical variables, and their respective predictor values for cluster membership. Where applicable, emphasis was placed on values that characterise each cluster.

The three clusters were 'labelled' based on their characteristics:

- Cluster 1 (N = 20/82). Medium-sized research locations, public-privately owned (40%), hosting research, and HEI (both 100%), with laboratory facilities for private use (90%), and relative low mix of other facilities. Leisure facilities are absent.
- Cluster 2 (N = 25/82). Large cooperative locations, both public-private (28%) and publicly owned (28%) cases are present, hosting research and HEI (both 100%), with laboratory facilities mainly for shared use (76%). There is a relative high mix of leisure and other facilities (modes are respectively 3 and 4).

[1] According to Formann (1984) the acceptable number of variables (m) is related to the sample size with $2^m = N$. Taking this rule of thumb into account, with a sample size of 82, cluster solutions with six variables would be appropriate. However, the additional seventh cluster variable allows for more insights on the clusters and the comparison between six and seven cluster solutions did not show vastly superior six-cluster solutions.

Table 6
Cluster comparison of 3-cluster solution.

Cluster variables	# of cases	%	Mode / mean	St. dev.	C1 (20)		C2 (25)		C3 (37)		Predictor
Research institutes presence	53	65			**20**	**100%**	**25**	**100%**	**8**	**22%**	1,00
Presence HEI	54	66			**20**	**100%**	**25**	**100%**	**9**	**24%**	0,95
Laboratory present	42	51			**18**	**90%**	6	24%	**18**	**49%**	0,59
Shared laboratory present	28	34			0	0%	**19**	**76%**	9	24%	
Laboratory absent	12	15			2	10%	0	0%	10	27%	
Mix of leisure facilities			0	0,17	**0**	**0,92**	**3**	**1,24**	**0**	**0,75**	0,33
Surface site (in 1000 m^2)			364	758	**288**	**413**	**846**	**1.177**	**79**	**177**	0,31
Mix of other facilities			2	2,14	**2**	**1,46**	**4**	**2,71**	**2**	**1,39**	0,26
Ownership											0,18
University	12	15			3	15%	2	8%	7	19%	
Public	21	26			0	0%	**7**	**28%**	**14**	**38%**	
Private	12	15			7	35%	1	4%	4	11%	
University-public	8	10			2	10%	4	16%	2	5%	
Triple helix	8	10			0	0%	3	12%	5	14%	
University private	1	1			0	0%	1	4%	0	0%	
Public-private	20	24			**8**	**40%**	**7**	**28%**	5	14%	

- Cluster 3 (N = 37/82). Small incubator locations, publicly owned (38%), research and HEI are absent (respectively 78% and 76%), with laboratory facilities for private use (49%). Almost no leisure facilities are provided. The mix of other facilities is relatively low.

4.4. Tests of significant differences

In order to distinguish each cluster solution in a more detailed way it was essential to investigate beyond the seven cluster variables that could describe differences between SP types. Therefore, differences between the resulting cluster solutions on omitted variables were analysed through tests of differences. Consequently, cluster differences can be compared statistically among variables that were not selected for clustering. The cluster analysis resulted in three clusters and in order to test the differences among these clusters three new dichotomous variables were required for cluster membership (0 = no and 1 = yes). The dichotomous variables for the presence of *work-related, leisure*, or *other facilities*, and *presence of services* were each tested on amenity level to reveal significant differences between clusters. The clustering variables *mix of leisure/other facilities* were also tested as dichotomous variables as this would reveal the specific facilities that were responsible for cluster membership.

Table 7 shows 17 dichotomous variables that contained significant differences between clusters. Significant levels were identified both on the .05 and the .001 level (2-tailed). The Fisher Exact-test was used to reveal the significant differences for the variables *SME, hotel,* and *residential housing presence.* This test is suitable for these dichotomous variables as they were relatively uncommon and therefore the expected value was lower than 5 for more than 20% of the cells of the 2 × 2 tables. Other significant differences were tested with Chi-square tests.

The first cluster research locations was the least times significantly different on attribute variables. Cases within this cluster tended to consist of *multiple buildings* (χ^2 = 5.85; p = .016). Services in terms of *consultancy* (χ^2 = 11.99; p = .001) and *venture capital* (χ^2 = 6.14; p = .024) were uncommon. This revealed that research locations were substantial in size and were geared towards R&D activities with less support for business growth. Almost all SPs in this cluster were active in *energy-related technologies* (χ^2 = 4.023; p = .045) as societal challenges are gaining attention from knowledge-intensive organisations (OECD, 2015). As indicated by cluster variable *surface site area,* cooperative locations were not only large in terms of square metres, but also were mainly *multiple building locations* (χ^2 = 4.85; p = .028) and provided space for *more than 100 resident organisations* (χ^2 = 6.68; p = .010). In contrast, cases with *less than 50 resident organisations* were uncommon in this cluster (χ^2 = 8.59; p = .003). For the large number of leisure facilities, significant differences were found at *sport centres* (χ^2 = 16.76; p = .000) and *sports grounds* (χ^2 = 20.16; p = .000). For other facilities

Table 7
Variables showing significant differences between clusters.

Variables	SPs		
	Research (20)	Cooperative (25)	Incubator (37)
Knowledge intensiveness			
SME presence	19	24	*27
Multinational companies presence	16	20	*19
Technology sector group			
Air, space, and land transportation technologies	9	11	*8
Energy-related technologies	*16	15	19
Size			
Multiple building location	*17	*20	**14
Number of resident organisations			
Less than 50 organisations	5	*3	**21
More than 100 organisations	8	*16	*11
Location			
Presence leisure facilities			
Hotels	4	10	*2
Sport centres	7	**17	**5
Sports grounds	3	**15	*4
Presence other facilities			
Banking	4	**12	**2
Child care	5	**18	**6
Medical	3	*11	5
Residential housing	4	8	*3
Shops (food)	8	*15	*7
Presence services			
Consultancy	*9	19	*33
Venture capital access	*9	20	25

Significant on p = .05* or .001** level (2-tailed).

that were more common, this was the case for *banking* (χ^2 = 14.24; p = .000), *child care* (χ^2 = 21.12; p = .000), *medical* (χ^2 = 8.76; p = .003) and *shops (food)* (χ^2 = 8.50; p = .004). Considering the large size of cooperative locations on several dimensions the provision of a large mix of facilities was expected. This suggested that these types of locations were providing next to core activities also non-work related facilities and thus offered more conveniences for users. On the other hand, incubator locations consisted mostly of *single building locations* (χ^2 = 17.01; p = .000), provided space for a smaller number of firms (χ^2 = 13.50; p = .000) and mainly SME's (Fisher's Exact-test p = .005). Furthermore, leisure facilities, such as *hotels* (Fisher's Exact-test p = .004), *sport centres* (χ^2 = 14.08; p = .000) and *sports grounds* (χ^2 = 8.81; p = .003) were found significantly less at this type of locations. In addition, the cases with *banking* (χ^2 = 10.77; p = .001), *child care* (χ^2 = 10.81; p = .001), *residential housing* (Fisher's Exact-test p = .044) and *shops (food)* (χ^2 = 9.07; p = .003) were significantly less common. Last, the large number of *consultancy* services were found significant (χ^2 = 7.75; p = .005), which suggested that incubator locations were largely aimed at business support. Although *venture capital access* was not significant, 68% of the cases of the incubator locations aided start-ups in growing their businesses. Resident firms at incubator locations were significantly less active within the sector group *Air, space, and land transportation technologies* (χ^2 = 4.703; p = .03). This is probably a result of their relative small size and therefore they are less likely to accommodate large-scale projects in sectors such as aerospace fields, which generally cover a large range of activities from experimental research to pre-production activities (OECD, 2015). The characteristics of incubator locations, such as the small size, absence of research institutes and HEI, lack of leisure facilities, and the focus on business support and growth, suggested that cases within this cluster are similar to the concept of incubators.

4.5. Discussion of results

Although the four themes are interrelated we will discuss our findings on each aspect separately. In terms of *knowledge intensiveness*, in line with Zhang (2002) our study showed that the two most important clustering variables measured the knowledge intensiveness of cases through the *presence of research institutes* and *HEI*. Compared to the two other SP types incubator locations were relatively less knowledge-intensive as these locations housed less research institutes and HEI. Moreover, the theme *size* was also considered by Zhang (2002) through ‘style’ (e.g. single building/incubator, park-style). Our cluster solution incubator locations was in line with Zhang’s incubator-style scheme. This cluster was significantly smaller than research and cooperative locations. Regarding the *organisation* of SPs Link and Link (2003) and Albahari et al. (2013b) distinguished SPs on the degree of university ownership (all university-related ownership models – i.e. *university, university-public, triple helix,* and *university-private*). Our study showed that within the three clusters, the variable ownership, and therefore university shareholding only predicted cluster membership to a relatively small degree. This revealed that in this European context, university shareholding was not a prerequisite for identifying SP types. The relation between cluster membership (categorical) and university-related ownership models (dichotomous) was not found significant (χ^2 = 1.27; p = .529). In contrast to some previous research which focused on technology sectors covered by SPs (e.g. Squicciarini, 2008; Liberati et al., 2016), we did not find significant differences between SP types with regard to this attribute. There is little evidence found on specific sectors within our sample. For the *location* theme there were various differences among cluster solutions. To a lesser extent incubator locations had significantly less shared usage of laboratories, which might limit personal encounters and knowledge transfer (Dettwiler et al., 2006). As expected, the two larger SP types are more likely to provide for a wider range of leisure and other facilities (i.e. hotel, sport facilities, banking, and child care).

In order to advance the conceptualisation of SPs we studied the (dis) similarities of distinct SP types. These insights could be used as input for explaining differences in firm performances. As SP impact was not inquired we will highlight three cases within our sample as examples. One of the cases classified as incubator location was Lispolis (PT) as at this SP no university or research institute is present and the main focus is urban and real estate development. Moreover, the scope and intensity of university links were essential for the growth of Portuguese SPs (i.e. job, revenue of tenants). (Ratinho and Henriques, 2010). Surrey Research Park (UK) is owned by a joint venture company consisting of public and private actors (the host university, local authority, business, and other investors) as a means to share costs and achieve policy objectives (e.g. increased technology transfer between university and markets, reputation, the creation and growth of new firms) (Parry, 2014). Within our cluster solution this SP is grouped among research locations where public-private ownership is one of the distinguishing characteristics. The key differences among research and cooperative locations are the presence of laboratories for shared use among resident firms and the larger range of amenities of the latter group. Among those cooperative locations is the High Tech Campus Eindhoven (NL) where the provision of shared resources and facilities were perceived by tenants as costly, but they do acknowledge that the resulting co-presence allowed them to meet people from other organisations (Van der Borgh et al., 2012). These repeated face-to-face interactions, communication, and information exchange are suggested to be the basis of innovation, knowledge creation, and learning (Bathelt et al., 2004). Within the ecosystem literature the existence of knowledge, business and innovation ecosystems has been identified with public knowledge organisations and private businesses as core members (e.g. Clarysse et al., 2014; Järvi et al., 2018). As SPs are one of the components of an ecosystem the mixed SP ownership and presence of a diverse community of tenants could aid value creation through knowledge transfer on one side and value capturing on the other.

The conceptualisation of the three SP types could further aid researchers in tackling the issue of heterogeneity among SP cases. The outcome of our work complements and builds upon recent studies on heterogeneity among SP characteristics of Fukugawa (2013) and Liberati et al. (2016). Our study showed that when taking into account a wider range of attribute variables, certain knowledge-related characteristics were highly distinguishing, while other characteristics studied by others were in lesser extent important to differentiate statistically distinct SP types. Therefore, the introduction of these homogenous SP types could aid past and future researchers in comparing and evaluating SPs or SP firms more adequately.

To conclude, the unique features and (dis)similarities among the three cluster solutions are summarised in Table 8. Empty cells denote that no significant differences were found.

Table 8
Summary of (dis)similarities of the three SP cluster solutions.

Variables	Research locations	Cooperative locations	Incubator locations
Knowledge intensiveness			
Research institutes	Present	Present	Absent
HEI	Present	Present	Absent
SMEs/multinationals			SMEs present / multinationals absent
Air, space, and land transportation technologies			Absent
Energy-related technologies	Present		
Size			
Site surface area	Medium	Large	Small
Single or multiple buildings	Multiple	Multiple	Single
Number of resident organisations		Larger number	Smaller number
Organisation			
Ownership	Public-private	Public-private/ Public	Public
Location			
Laboratories	Present	Present and shared-use	Present
Mix of leisure facilities	0	3	0
Hotels			Absent
Sport centres		Present	Absent
Sports grounds		Present	Absent
Mix of other facilities	2	4	2
Banking		Present	Absent
Childcare		Present	Absent
Medical		Present	
Residential housing			Absent
Shops (food)		Present	Absent
Consultancy services	Absent		Present
Venture capital access	Absent		

5. Conclusions and limitations

In the past decades the majority of academic research in this area has focussed on SP impact on firm performance, but no uniform evidence has been found for improving innovative output, economic performance or networking among resident organisations. It is argued that the search for the evidence of SP impact is relevant for society, as these objects are often funded by the public sector (Monck and Peters, 2009). Some authors stated that mixed performances of SP resident organisations was a result of neglecting the features of the SP itself, i.e. the structures providing space and services for these residents (e.g. Siegel et al., 2003a; Capello and Morrison, 2009). We therefore argued that before academics can evaluate the performance of SP resident organisations ('what they do'), more attention is needed for the structures that house these organisations ('what they are'). This paper fills this knowledge gap by introducing descriptions of three distinct SP types that could make comparing firm performance and benchmarking SPs more useful and appropriate. The three SP types are labelled as research locations, cooperative locations, and incubator locations. In addition, this study adds to the growing body of knowledge by discussing important SP characteristics. The key contribution of this study to the existing broad SP literature is that a method is presented that combines previous characteristics of classifying attempts and produces three statistically sound SP types. Previous efforts are characterised by their qualitative nature and limited number of distinguishing variables, therefore only studying certain aspects of the SP concept. This study contributes to prior research limitations through quantitative methods with a larger sample size and a wider spectrum of attribute variables.

Previous research has often used 'university ownership' as the main distinguishing characteristic (Link and Link, 2003; Albahari et al., 2013b). However, within the three SP types this was not the case, which reveals that ownership of SPs has become more diverse including public and/or private SP owners. Our cluster analysis showed that ownership structure was the least important variable to distinguish distinct types. Also, no significant differences were found between SP types on characteristics, such as R&D facilities (clean/pilot rooms) and technology sector focus. It was expected that in practice these characteristics would be significantly different as R&D facilities are often offered at more specialised SPs focused on the biotechnology and life sciences sector. On the other hand, incubators are present at almost all cases, which implies that (new) SPs should at least consider providing these facilities.

Based on our findings we are able to refine the SP definition of the IASP. This definition is used most often by academics and practitioners and is considered by academics to be broad due to its application to a large number of SP-related objects. This paper revealed what a SP could 'be', while the IASP definition described what it should 'do'. Through our empiric research we have further refined this definition. In accordance to the IASP definition we saw that within our sample, SPs without a management function were almost non-existent and that the on-site management company was most common. The current study showed that the most distinguishing variables were the presence of knowledge-intensive organisations and the ability to conduct knowledge-intensive activities (laboratories), and to a lesser extent size of the location. Furthermore, we revealed which facilities and services were most distinguishing within the European context. We revealed that laboratories, leisure and support facilities, and business development services (i.e. consultancy, and venture capital services) were relative important to discern SP types. We offered a more comprehensive description of the three SP forms and made the general accepted SP definition even more explicit. Consequently, in terms of what a SP could 'be', we propose the following definition; *A SP is a real estate or area development, managed by an on-site management company. It is home to knowledge organisations, such as research institutes, HEI, and firms in all business development phases. Resident organisations can make use of a wide range of shared or private facilities, such as R&D facilities, business support, leisure and other amenities. Based on variations of these characteristics a SP typology consisting of <u>incubator locations, research locations, and co-operative locations</u> can be distinguished.*

This study has several managerial implications; it offers a general overview of the current state of the European SP context and characteristics. Moreover, the outline of the three SP types provides public entities insight on evaluating future investment alternatives. It gives potential investors means to explore various SP types they want to invest in. For resident organisations seeking bases for operations our SP typology presents distinct descriptions to compare alternative locations. In addition, characterisation of these SP types provides current SP managers/owners with a better understanding of what makes their SPs distinct. The various SP types and their distinguishing characteristics can be used to market SP locations more effectively. Furthermore, it gives SP managers valuable insights for seeking similar locations as suitable competitors for benchmarking purposes. Moreover, our findings might also have important implications for policy. It is generally accepted that innovation is strongly affected by its context and public authorities have long recognised that they need to engage policies and tools to create a suitable environment for innovation. However, creating such an environment is not an easy task and to enhance the effectiveness of policy instruments, it is vital to distinguish between different types of contexts (Autio et al., 2014). Our study contributes to this call for heterogeneity, by offering an overview of the current state of the European SP context. Such an overview provides policy makers with relevant preliminary insights as it is reasoned that different SP types have a distinct effect on innovative performance (Albahari et al., 2013b) and public support systems need to vary accordingly. Consequently, understanding the characteristics of distinct science park types is an important first step towards a more fine-grained evaluation of the effectiveness of different policy actions.

However, there are a few limitations that could also serve as input for future research. Although the international sample is uncommon in SP research, the sample was small compared to the total European SP population. Additionally, the majority of the SPs within the sample were established within the Netherlands and the UK, while other typical SP countries, such as France and Germany were less represented. As Eastern European countries were underrepresented in our sample, future research should explore science park locations in that region and adopt a multilingual approach in order to increase the response rate. Moreover, within our exploratory segmentation of SPs we did not take into account the national innovation system per country which SPs are an integral part of. Future multinational studies with larger sample sizes of SPs could take into account measures that address this aspect, i.e. amount of public or private R&D investments, number of educated workforce or employment in high tech industries (Albahari et al., 2013a). Due to the limited number of SPs per country our sample did not reflect the diversity of economic development among different national innovation systems (Nelson, 1993). The European SP sample limits the international generalisability of the research findings. As SPs are spread globally, the question arises whether similar or other types emerge in other strong SP regions such as North America and Asia. Moreover, this exploratory study is one of the first to propose a SP typology through cluster analysis to be based on the included sample parks and characteristics. Future research should address other possible configurations of variables and other interesting quantitative measures. At both research locations and cooperative locations, research institutes and HEI are present. Within the ecosystem literature these actors can function as anchor tenants or keystone players that create and/or share value with other organisations within the SP (Clarysse et al., 2014). According to Clarysse et al. (2014) policy makers assumed that the creation of knowledge ecosystems (value flowing linearly from upstream to downstream) would ensure the development of business ecosystems (non-linear networked value creation). Future research on SP segmentation could include the investigation of ecosystems types that have developed and the policy success of the creation of business ecosystems.

With our study we have produced an outline of the various SP forms, contributing to the further empiric conceptualisation of the SP. As we have advanced the academic debate on what a SP could be, future research can focus on the relation between SP types and firm or SP performance opening new venues of SP evaluation. Another possible venue for further exploration includes the needs of SP firms. Prior research has given some attention to location benefits perceived by firms (e.g. Westhead and Batstone, 1999; Lindelöf and Löfsten, 2003). This would shed light on the demand-side of the SP, traditionally a supply-oriented policy instrument (Edler and Georghiou, 2007). As shared use of laboratories is one of the clustering variables, further detailed data is required for size, type, and equipment, as this variable was only represented on a categorical level. Respondents indicated that shared usage can be quite diverse (e.g. in-house facilities with some shared facilities or access to university facilities). This suggests that further exploration of what and how facilities are shared on a science park is relevant, as sharing facilities could facilitate interactions and knowledge transfer (Dettwiler et al., 2006). A crucial point to make is that within this study clustering variables were what make these SP styles distinct; i.e. future research is required for the impact of SP types. Namely, variables that are present at almost all cases were not addressed in detail (e.g. networking events, different types of work-related facilities). Previous studies comparing firm performances could adopt these SP types to evaluate differences among SP cases and this could result in different firm performances.

Conflicts of interest

None.

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Appendix A

See Table A1

Table A1
Knowledge intensiveness variables with frequencies (N = 82).

Variables	Value	
Presence of HEI (dichotomous)	Present	54
Presence of research institutes (dichotomous)	Present	53
Presence of small medium and/or multinational companies (dichotomous)	Present	72
Sectoral focus of the tenant organisations (categorical)	Uniform focus; 1 sector group	12
	High focus; 2 or 3 groups	20
	Medium focus; 4 groups	19
	Low focus; 0 or 5 or more	31

Appendix B

See Table B1

Table B1
Size variables with frequencies (N=82).

Variables	Value	
Site surface area (continuous)	[m^2] min 80 – max 5.300.000; st. dev. 758.700	Average 64.400
Single or multiple buildings (dichotomous)	Single building location	31
	Multiple buildings location	51
Number of resident organisations (categorical)	Less than 50	29
	Between 50 and 100	18
	Between 100 and 200	19
	Between 200 and 400	11
	Between 400 and 600	4
	Between 600 and 1000	1

Appendix C

See Table C1

Table C1
Organisation variables with frequencies (N = 82).

Variables	Value	
Ownership structure (categorical)	University	12
	Public	21
	Private	12
	University-public	8
	Triple helix	8
	University-private	1
	Public-private	20
Management function (categorical)	No management function	2
	Informal teams	7
	Single on-site manager	20
	On-site management company	53
Age of the location (continuous)	[Years] min 2 – max 33; st. dev. 9,3	Average 14,5

Appendix D

See Table D1

Table D1
Location variables with frequencies (N = 82).

Variables	Value	
Urban context (categorical)	City contains the location	26
	Location overlaps the city	18
	Location touches the city	19
	Location is disjointed from the city	12
	Multiple locations	7
Mix of work-related facilities (ordinal)	min 2 – max 6 (i.e. auditorium, conference room, eating, exhibition room or showroom areas, library, meeting rooms)	Mode 4
Mix of leisure facilities (ordinal)	min 0 – max 4 (i.e. cinema, hotel, sport centres, sports grounds)	Mode 0
Mix of other facilities (ordinal)	min 0 – max 9 (i.e. banking, child care, cleaning and maintenance, medical, residential housing, safety and security, shops (food), shops (non-food), travel agency)	Mode 2
Mix of services (ordinal)	min 0 – max 11 (i.e. accounting, administrative services, consultancy, graphical design, information access, management support, marketing, networking events, training, venture capital access)	Mode 7
Laboratory (categorical)	Present	42
	Present and for shared usage	28
	Absent	12
Incubator (categorical)	Present	25
	Present and for shared usage	53
	Absent	4
Cleanroom (categorical)	Present	24
	Present and for shared usage	15
	Absent	43
Pilot room (categorical)	Present	17
	Present and for shared usage	27
	Absent	38
Presence manufacturing space (dichotomous)	Present	54

Appendix E

See Table E1

Table E1
Predictor values for cluster membership of all variables.

			Knowledge intensiveness			Size			Organisation			
Cluster solutions	Cluster cohesion	Cases within subclusters	HEI	Research institutes	SMEs/ multinationals	Single /multiple buildings	Surface area site	# of organisations	Ownership structure	Management function	Technology sector focus	Age
1a	.4	45 – 37	.95	1			.22		.09			
1b	.3	37 – 25 – 20	.95	1			.31		.18			
1c	.2	20 – 19 – 19 – 13 – 11	.65	.83			.26		.41			
2	.4	47 – 35	.83	1		.49		.20	.10			
3	.4	45 – 37	.95	1		.35	.22		.09			
4	.4	54 – 28	1	.32		.11	.10			.05		
5	.4	46 – 36	.84	1		.36	.20				.08	
6	.4	45 – 37	.86	.91		1	.41					.19
7	.4	45 – 37	.95	1			.22		.09			
8	.4	45 – 37	1	.83			.19		.06			
9	.4	45 – 37	.95	1			.22		.09			
10	.3	24 – 23 – 21 – 14	.7				.12		.34	.35		
11	.3	30 – 28 – 24			.13			.06	.07	.21		
12	.3	68 – 14	.15					.39			.59	
13	.3	68 – 14			.13			.39			.59	
14	.3	67 – 15			.12		.10				.48	
15	.3	59 – 23	.10				.03				.18	
16	.3	62 – 20	.46				.08				.40	
17	.3	46 – 36	1				.12			.13		
18	.3	42 – 40	.21				.02			.05		
19	.3	48 – 34		.31		1	.22			.03	.09	
20	.3	48 – 34	.86	.78		1	.47	.15	.26			
21	.3	41 – 41	.95	1		.62	.33					.24
22	.3	70 – 12		.26			.12				.37	

(*continued on next page*)

Table E1 (*continued*)

Cluster solutions	Location								
	Urban context	Mix of leisure facilities	Mix of other facilities	Mix of services	Laboratory	Incubator	Clean room	Pilot room	Manufacturing space
1a		.25	<u>.09</u>		.15				
1b		.33	.26		.59				
1c		.42	.56		1				
2				.16					<u>.02</u>
3		.25			.15				
4		.08			.06				
5		.27			.15				
6		.34			<u>.11</u>				
7		.25	.09			<u>.06</u>			
8		.25	.11				.14		
9		.25	.09					<u>.03</u>	
10					.52		1	.92	
11					.40		1	.46	
12		1	.75		.99		.88		
13		1	.75		.99		.8		
14		.84	.62		1		.87		
15		.25	.21		1		.4		
16		.56	.6	.12	1				
17	.12			<u>.09</u>		.17			.29
18	.09				.04	<u>.01</u>			1
19					.23		.14		
20					.17				
21		.72					.28		
22		1	.67		.67		.57		

Each row describes a cluster solution derived from auto-clustering within the Twostep clustering method, followed by the silhouette coefficient indicating cluster cohesion, number of cases per subcluster and the predictor values per variable (0–1). The cluster solutions are grouped on descending order of cluster cohesiveness and each solution varies among chosen cluster variables. Lowest predictor scores per cluster solution were underscored. The input variables of variant cluster solutions were the same, however the number of subclusters was different. ‘Mix of work-related facilities’ was excluded because cluster solutions containing this variable did not have a cluster cohesiveness of .3 or higher. This could be explained by that most cases provided a similar large number of work-related facilities, thus limited its contribution to predicting cluster membership.

Appendix F

See Table F1

Table F1
Output Auto-Clustering BIC and AIC.

# of Clusters	Schwarz Bayesian Criterion	BIC Change	Ratio of BIC Changes	Akaike Information Criterion	AIC Change	Ratio of AIC Changes	Ratio of Distance Measures	Silhouette coefficient
1	1366,585			1306,417				
2	1304,481	−62,104	1,000	1184,145	−122,272	1,000	1,610	0.4
3	1307,618	3,137	-,051	1127,115	−57,031	,466	1,296	0.3
4	1335,169	27,551	-,444	1094,497	−32,617	,267	1,002	0.3
5	1362,845	27,676	-,446	1062,005	−32,492	,266	1,513	0.2
6	1418,497	55,652	-,896	1057,489	−4,516	,037	1,099	0.2
7	1479,043	60,546	-,975	1057,867	,378	-,003	1,127	0.2

Appendix G

See Table G1

Table G1
Comparison cluster solutions.

Cluster	n	%	id cases of 3-cluster solution																			
1	20	24	5	9	13	22	32	37	46	56	60	62	63	64	65	68	69	71	72	76	77	80
2	25	30	1	2	3	7	14	15	23	25	26	28	30	34	35	38	43	45	48	54	57	58
			70	74	79	81	82															
3	37	45	4	6	8	10	11	12	16	17	18	19	20	21	24	27	29	31	33	36	39	40
			41	42	44	47	49	50	51	52	53	55	59	61	66	67	73	75	78			
Total	82	100																				
Cluster	n	%	id cases of 5-cluster solution																			
1	19	23	5	9	13	22	32	37	46	56	60	62	63	65	68	69	71	72	76	77	80	
2	11	13	64	1	14	15	34	48	54	58	79	81	18									
3	20	24	2	3	43	82	10	11	12	19	20	27	31	36	39	41	47	49	51	66	67	75
4	13	16	7	23	25	26	28	30	35	38	45	57	70	74	73							
5	19	23	4	6	8	16	17	21	24	29	33	40	42	44	50	52	53	55	59	61	78	
Total	82	100																				

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