Demand-driven science parks

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The Perceived Benefits and Trade-offs of Tenant Firms with regard to Science Park Attributes

Wei Keat Benny Ng

Bouwstenen 283

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This PhD dissertation is what some would say to be a culmination of a four year long journey. Here, I want to reflect on this journey and give my thanks to those that were a part of this personal adventure. My decision to do a PhD probably lies in my curiosity and passion for getting to know how things work. It was therefore a pure coincidence that a PhD position was available at my former university department on the topic of science parks, which I already had some affinity with during my masters and my work as a consultant. At that time I considered myself a generalist and I was really looking to specialise in a certain topic. A PhD project would greatly serve that purpose.

This journey started in January 2016 and I must say that immediately I had some mixed feelings about it. I expected the extensive reading of literature and building my own knowledge base, but the individualistic approach of doing research was somewhat of a setback. Personally, this sudden change from the teamwork approach from consultancy to doing research on my own was something that I at first struggled with. As time progressed I accepted this change. I refocused myself on finishing this PhD on a timely and acceptable fashion. In these four years, I have gained some knowledge on science parks and visited academic conferences held at amazing cities, including Cergy-Pontoise, Delft, Hong Kong, Manchester, Moscow and Reading. Furthermore, conducting research has been rewarding for me as I was able to investigate things that are of public interest. Looking back on these years I have studied science parks with great passion and conducting interesting research is what gives me energy. The personal aim to conclude this journey in four years helped me to persevere and be resilient. But most importantly, I met a lot of amazing people and made new friends. There are some that I need to thank in particular.

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When one journey ends, another begins…

Summary

Demand-driven Science Parks

The Perceived Benefits and Trade-offs of Tenant Firms with regard to Science Park Attributes

Technology development is increasingly important for creating efficient and sustainable economies. One of the innovation policies to stimulate technology development are science parks, area developments where technology-based tenant firms and knowledge-based institutions co-locate. Science parks as knowledge-intensive area developments aim to enhance networking, and innovative and economic performance of firms and regions. Although science parks are established globally for decades, there is limited research into possible types within these real estate objects. Furthermore, the perceived benefits and trade-offs of tenant firms regarding what science parks offer have not been made clear yet. Preferences of tenant firms for design-related attributes relate to the presence of certain facilities, services, and location attributes, which are means for achieving organisational goals. As science parks are locations that offer a mix of such facilities and services to a wide range of tenant firms, they can be configured in numerous ways. The gap between what science parks offer and what tenants need has been acknowledged as troublesome by science park managers and tenants as this gap can negatively influence the performance of science parks and their tenants.

Consequently, this PhD research aims to investigate the supply and demand-side of science parks in order to provide input for the development and management of science parks that fit the needs of the different tenant firms. Within the science park context, the supply-side consists of design-related attributes, such as geographical location, buildings, facilities and services, which may differ largely between science parks. The demand-side consists of the different perceived benefits and trade-offs (i.e., preferences of the design-related attributes) of technology-based firms and other resident organisations towards that what a science park can supply to them. This study contributes to three interrelated topics within the science park context: deriving a typology of science parks regarding relevant attributes, the perceived benefits of tenant firms in relation to science park attributes and the preferences of tenant firms with regard to design-related attributes of science parks and their willingness to pay for these attributes. In order to contribute to these topics, four different sub studies are followed.

First a survey on science park characteristics is completed by science park managers in Europe. A cluster analysis grouped the 82 participating science parks in three types: 'research', 'cooperative', and 'incubator' locations. The presence of research institutes, universities, access to R&D facilities, leisure facilities, park size and ownership are the most distinguishing characteristics. The differences and similarities of these three types of science parks in Europe are analysed as a basis for advancing the academic debate. The second study focuses on science park facilities and services and how firms perceive the benefits associated with these attributes. A survey distributed among tenants on seven science parks in the Netherlands was completed by 103 respondents. An a priori list of science park attributes was presented in order to gain insight in how the respondents associated these facilities and services with potential benefits. The benefits considered were derived from proximity and innovation literature within the science park context. In general, science park attributes are associated with either proximity benefits or benefits related to the science park real estate. Based on a cluster analysis of the organisational characteristics that were collected, three tenant types are identified. The three tenant types seek different benefits through different attributes. Commercially-orientated firms associate science park attributes as ways for being near customers, while mature science-based firms associate attributes with a wider range of benefits, such as image benefits, being near customers and other firms. Young technology-based firms are more cost-driven and focus on image benefits.

In the third study, association pattern data between twenty science park attributes with twelve benefits is collected through a survey involving 51 firms on science parks in the Netherlands. Here, a larger range of attributes are included, such as proximity to the university and other organisations, real estate-related attributes and managerial attributes of the science park. The benefits that tenant firms might perceive, are adopted from existing science park evaluation research. Results show that both proximity and managerial attributes are associated with economic, innovation and networking benefits, while real estate attributes are mainly linked to economic benefits. The role of science park management and their activities are acknowledged by tenants as important. According to tenant firms, science park management is beneficial for developing ties with other firms, while they seem to fulfil only an indirect role in enhancing innovation.

In the final study, a survey is distributed among 69 technology-based firms both on and off science parks in the Netherlands. Using the technique of stated-choice experiments, decision-makers of firms are presented carefully designed hypothetical science park locations and asked to indicate which location they would prefer if they would relocate. In the experimental design used, each hypothetical location consists of seven design-related attributes each with three possible quality levels. The choice data allows for estimating the utility assigned by tenant firms to the different levels of each attribute, using a discrete choice model as framework, while considering interactions with the respondent's organisational characteristics. In addition, this method provides insight into the trade-off among the considered design-related attributes and tenant firms' willingness to pay for these attributes.

The analyses show that among the seven attributes, the most important aspect is cost of use, followed by in decreasing importance the presence of a university, R&D facilities, location type, shared facilities, sectoral focus of other firms and events organised. Firms on a science park prefer locations near stations and with a university within the same area relatively more strongly than firms not located on a science park. Furthermore, science park tenant firms prefer the provision of shared business support and leisure facilities on these parks relatively more than firms not located on science parks. In general, tenants are willing to pay the most for locations with a university within the same area, followed by, in decreasing importance, R&D facilities for private use, suburban locations, shared business support facilities, areas with firms active in the same technology domain, and lastly networking events.

Overall the results from this PhD research provide insights in what science parks are, what they mean for tenant firms and their willingness to pay for the quality levels of important attributes. Firstly, the distinction in science park types provides further understanding of science parks and offer researchers, practitioners, and policy-makers a means to compare, market, and benchmark science parks more adequately. Secondly, the associations made by tenant firms between attributes and the benefits, provide additional insights for theory and practical implications. Science park tenant firms represent a heterogeneous group and different types of tenants should be distinguished as they differ in needs and therefore the science park impact might not be uniform among all firms. For practitioners the values of attributes for firms can inform decision-making in the design and management of science parks. Finally, for theory the stated choice experiment provides insights in preference differences between firms related to firm characteristics. The design-related preferences allow policy-makers, real estate developers and science park managers to reconsider those attributes that are important for tenants within the context of knowledge-intensive area developments, demand estimation and evaluation of existing science parks.

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PART I

Research Design

CHAPTER ONE

Introduction

Through the last decades the main mission of science parks has varied from fostering collaboration between university and industry to regional development and ultimately increasing the efficiency of innovation (Bigliardi et al., 2006). On macro-level, they mainly address market failures, such as encouraging R&D to take place at specific locations (Appold, 2004). On micro-level, hosted firms share facilities and services, which allows them to avoid large capital investments in expensive facilities, optimise use and promote synergy (Brinkø et al., 2014; Van Winden et al., 2015). Science parks have existed since the 1950s and have gained increasing attention from academia since the 1990s in regard to their impact on firm performance. According to Albahari et al. (2010), the impact for tenant firms located on a science park can be categorised in three dimensions: economic performance, innovative activities and the relationship with academia.

Existing evaluative research of science park impact on firm performance has shown limited evidence of enhanced economic performance, contrasting evidence on innovative activities, but positive effects have been found for developing links with academia (Albahari et al., 2010). However, within existing evaluation studies little attention is given to the characteristics of the science parks themselves (Ramírez-Alesón and Fernández-Olmos, 2018). In addition, according to Mora-Valentín et al. (2019) the science park literature has largely focused on their impact on innovation performance; future research could focus on topics related to the creation and development of science parks. 'Located on a science park' is often merely a firm variable within these studies, which suggests that science parks are a homogenous group. Besides the issues surrounding the impact and conception of a science park there exists some additional concerns related to its terminology. The term 'science park' is used interchangeably in different studies with other similar terms such as 'research park', 'innovation centre', 'hi-tech park' or 'science and technology park' (Hansson et al., 2005). And even if science parks are observed as a means to offer facilities and services to a group of tenants, there would be countless configurations possible (Etzkowitz and Zhou, 2017). As a real estate-based policy tool, the means of a science park consist largely of the location itself, presence of knowledge-based organisations and facilities and services to contribute to the objectives of tenant firms.

Of all types of firms the technological start-up or the new technology-based firm has gained the most attention in existing research. This is a result of the policy goal of the science park to support the development of technology-based firms (Good et al., 2019). However, science parks are not only home to these smaller and younger technology-based firms, but also more established firms, research institutes and service providers are located on science parks (Van Der Borgh et al., 2012).

The needs and goals related to their business location of firms active in different business development phases are likely to be very different (Chan and Lau, 2005). Consequently, finding the right configuration of demand-driven science parks is challenging as these properties often house a large range of different science park tenant firms with possibly different needs. The potential gap between the supply of facilities and services and the needs of tenant firms is acknowledged by science park managers as troublesome (Albahari et al., 2019).

Thus, it seems that overall there is limited attention given to the possible heterogeneity among science parks and the different tenant firms, and as a result the needs of these different types of firms have been largely neglected. Therefore, this thesis aims to contribute to these issues raised regarding the demand-side. This demand-driven approach follows a recent call for research into perceptual measures of benefits firms obtain from being located on a science park (Albahari et al., 2019; Lecluyse et al., 2019). In order to contribute to the demand-driven science park development, needs of the firms should not be studied in isolation, but also the trade-offs that firms make in their location choice are important. Because resources are limited, decision-making processes should take a wide range of attributes in consideration and take into account the relative importance, i.e., cost and quality, of attributes (Hensher et al., 2015).

A demand-perspective contributes to both practice and literature. For practice, the perspective of the tenant firm provides the science park managers with more detailed input regarding the development of the knowledge-based area and help them to achieve more effective and future-proof science parks. For literature, which focused mainly on the impact of the science park location on firm performance, the present thesis contributes by delving into the supply-side of science parks through their attributes, while considering the demand of the tenant firms. Compared to firm performance measures, perceptual measures are suggested to be better able to account for the different objectives among different firms (Lecluyse et al., 2019). Schematically this thesis aims to investigate the relation between the supply and demand-side of science parks from the perspective of tenant firms (see Figure 1). The topics and chapter titles of this PhD research are italicised.

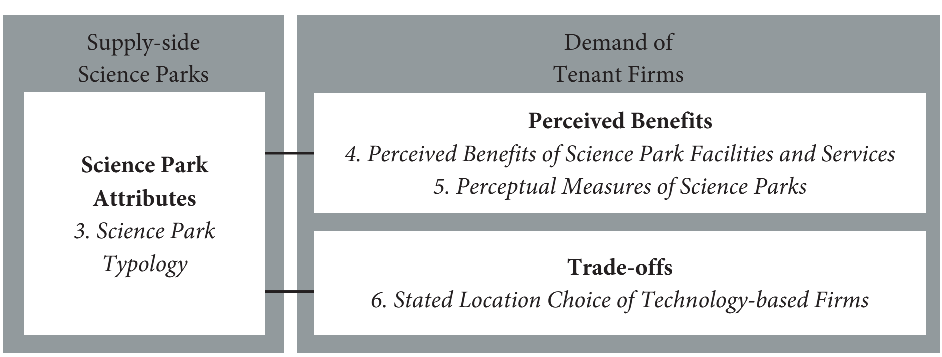


Figure 1 Schematic overview of the research focus of this thesis

Within the science park context, the supply-side consists of the design-related attributes which may vary largely across science parks (e.g., geographical location, buildings, facilities and services). The demand-side consists of the different perceived benefits and trade-offs (i.e., preferences for the design-related attributes) of technology-based firms and other resident organisations towards that what a science park can supply to them.

From an economic perspective, the supply of real estate is inelastic as a result of the long lifespan of buildings, while the demand for adequate space and quality can be more dynamic and related to the needs of users (Geltner and Miller, 2001). As science parks are commonly funded partially by public sources there is a sense of responsibility for proper resource allocation for current and future science park projects (Monck and Peters 2009). A potential mismatch between the supply-side (i.e., science park offering) and the tenants' demand might negatively impact the performance of tenant firms and also imply that policy goals are not accomplished. For policy-makers, these consequences could jeopardise their objective of supporting the development of technology-based firms (Good et al., 2019).

1.1. Research objective and questions

The objective of this thesis is to understand the science park concept through considering the supply- and demand-side of science parks, while accounting for the heterogeneity among science parks and its tenant firms. Formally, the objective is defined as:

To identify different science park types and analyse the needs and trade-offs of its different tenant firms with regard to design-related science park attributes in order to provide input for the development and management of science parks that fit the needs of the different tenant firms.

The main research question is:

"Which types of science parks can be distinguished and what are the perceived benefits and trade-offs of science park tenant firms with regard to important science park attributes?"

This thesis aims to contribute to three interrelated topics within the science park context: the identification of different types of science parks, the perceived benefits of tenant firms in relation to science park attributes and the trade-offs of tenant firms with regard to design-related attributes of science parks.

In order to achieve this objective four different research questions tied to four separate studies are answered in this dissertation. The first research question addresses the identification of different science park types. The second and third research questions focus on the benefits science park tenant firms perceive through the science park attributes. The last research question refers to the trade-offs made by technology-based firms among design-related science park attributes.

1) What are the main characteristics of science parks and which science park types can be distinguished?

2) Which benefits do science park tenant firms associate with science park facilities and services and does this perception differ among tenant types?

3) Which benefits are perceived by science park tenant firms and which science park attributes are associated to which perceived benefits?

4) How do technology-based firms make trade-offs between design-related science park attributes?

1.2. Filling the gap

From a policy perspective, science park development involves (financial) risks and it is therefore essential not to take one basic science park model for granted, but rather to further investigate the science park concept for better decision-making (Morlacchi and Martin, 2009). Moreover, discussion on science park impact remains challenging if a shared segmentation is missing (National Research Council, 2009; Ferrara et al., 2015). Although there are clear examples of science parks that are successful in enhancing firm performance, the conditions that result in successful science parks remain unknown (Yang et al., 2009). The exploration of distinct types is required from a policy perspective as various regions have different objectives and therefore call for different policy implementations. A typology therefore can move the debate forward regarding different firm benefits as a result of being located on different science park types (Siegel et al., 2003b; Saublens, 2007; Capello and Morrison, 2009) and would make assessing of science park performance less complex (Lamperti et al., 2017). The scientific discovery of different science park types could also offer practitioners (e.g., project developers, investors, science park managers) useful input for the adequate design, development, operation and evaluation of science parks.

The study into the perceived benefits offers a novel contribution to the science park literature and provides insight in the associations made by science park tenant firms between perceived benefits and the provided attributes. Moreover, it offers useful information for innovation policy management and science park knowledge both in a scientific and a practical way. The theoretical contribution leads to a further understanding of the science park concept and knowledge-based area development in general with a focus on the needs of tenants (Mora-Valentín et al., 2018). Insights into perceived benefits lead to a better understanding of how science parks impact tenants. For the design and management of science parks, the provision of specific facilities and services can be considered as means to create value and to enhance the overall performance of the science park itself or its tenants. Moreover, for urban planners and science park management, the user-focused approach supports more effective science park planning and management and development of science park configurations that align with current tenants' needs. The study of trade-offs made by technology-based firms adds to existing research and is an extension of the study on perceived benefits (e.g., Westhead and Batstone, 1999; Ferguson and Olofsson, 2004; Dettwiler et al., 2006).

In general, these studies examine the importance of various science park attributes as individual measures, but the relative importance or trade-offs that technology-based firms make among typical attributes remain unknown.

The research gap asks for a strong research focus on the science park's 'inner environment', which consists of the location, facilities and services provided to and used by tenant firms. In contrast, the 'outer environment', i.e., the regional innovation system and subsequent national innovation system (Nelson, 1993; Cooke, 2001), will therefore not be the main focus in this thesis. The outcome of this study of the 'inner environment' of science parks will have implications for ways to achieve policy goals described by their 'outer environment' (Simon, 1996).

1.3. Research design

In this section, first the research philosophy for this dissertation is discussed. Then the research method that contributes to achieving the research objective is described. Lastly, the outline and the content of the chapters of this dissertation are discussed.

1.3.1. Research philosophy

The essence of research is acquiring specific knowledge on a certain subject, which was previously unknown (i.e., the research gap). Within business and management research there are five different research philosophies that influence the chosen research design and therefore the development of knowledge, see Figure 2 for the 'research onion' (Saunders et al., 2018). These philosophies are: 1) positivism, which focuses on causal explanations of the world through facts that are measurable and observable (Saunders et al., 2018); 2) critical realism - the separation of the worldview in experiences, events and mechanisms (Bhaskar, 2008); 3) interpretivism - the notion that occurrences can be interpreted in different ways (Galliers, 1991); 4) postmodernism is the stance that opposes a single objective truth, because dominant views should be challenged in a critical way (Saunders et al., 2018); 5) pragmatism - the notion that concepts are only relevant if they initiate practical action (Kelemen and Rumens, 2008).

Considering the research questions posited in section 1.1, which focuses on the possible heterogeneity among science parks, tenant firms and causal relation between science park attributes and benefits, it is therefore fitting to adopt a positivist or empirical stance for this dissertation. The empirical approach for this thesis is based on quantitative data collection and statistical testing, which contributes to attaining the proposed research goal. Throughout the different sub studies the existing empirical science park research will be reviewed and further developed where possible from a neutral point of view. Furthermore, a pragmatic stance is also vital for the formulation of the implications for theory and practice (see section 7.2). The possible stakeholders surrounding science parks range from policy-makers, real estate practitioners, science park management, universities and tenant firms. The practical implications as discussed in section 7.2.2 will therefore address the perspectives of these different stakeholders.

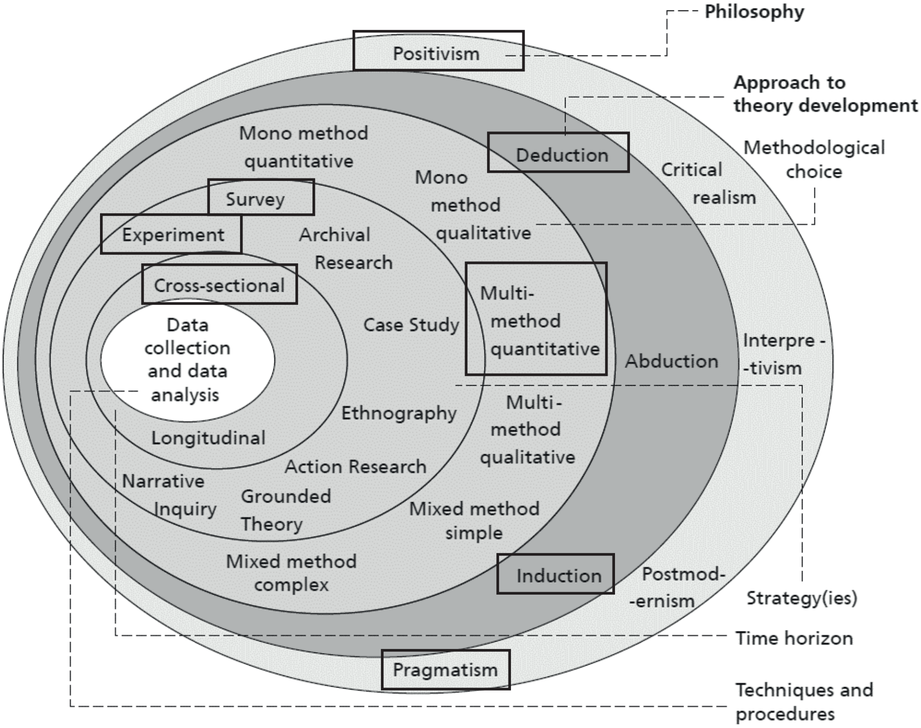


Figure 2 The 'research onion' with the adopted choices in boxes (Saunders et al., 2018)

In terms of the possible different approaches for theory development, this research will apply both deduction and induction across the four sub studies. Data collection is used for both proposing possible explanations through logic from the results (deduction) and deriving general conclusions from observed data, i.e., sample of science parks or firms (induction).

To account for heterogeneity among science parks and firms, a multi-method quantitative approach using surveys is chosen. Different quantitative methods are required as the research objective involves distinguishing sub groups among a collection of science parks and firms, evaluating the relation between attributes and benefits and analysing the trade-offs between science park attributes of firms. Statistical testing of relationships found in survey data allows for generalisation (positivism), but potential systematic biases in responses of respondents or sample representativeness issues could be a problem (Galliers, 1991). These problems can be relieved through procedures such as a test for non-respondent bias (Armstrong and Overton, 1977) and use of control groups (firms located on and not located on science parks). Moreover, for analysing the trade-offs an experimental approach is chosen to identify effects of decision-making of firms.

As this thesis aims to contribute to multiple science park topics (i.e., segmentation, perceived benefits and trade-offs) within a limited time frame, each research problem will be addressed by collecting cross-sectional data. The longitudinal approach is less desired from a practical point of view, as this method also requires long-term respondent commitment from target respondents that often have tight schedules (e.g., science park managers, executives).

1.3.2. Research method

In order to achieve the research objective, the interrelated research questions are answered through four different self-contained sub studies, each with a separate quantitative data collection. The first study intends to provide an answer to what science parks are, but not what makes them important to its users. The second and third study add to the first study as they intend to reveal what attributes are important and how these are associated with perceived benefits. However, these associations between attributes and benefits are each evaluated separately by tenant firms. Therefore, the fourth study examines the trade-offs that technology-based firms make given these important science park attributes.

The geographical focus of these studies lies primarily on the Netherlands with an exception for the first study on science park typology. The first study adopts an empirical and inductive approach with limited emphasis on theory, which is in line with research on science, technology and innovation policy focussing on practical problems surrounding a specific policy measure (Morlacchi and Martin, 2009). The European level is chosen as it enables to compare potential differences among regions in Europe and lead to far more cases than when the scope would be limited to the Netherlands. At the time of the analysis of this study only approximately 35 of these science park-like locations were located in the Netherlands (Buck Consultants International, 2014), which does not allow for quantitative segmentation. In order to distinguish differences among European science parks, an online survey is distributed among managers of science park-like locations in Europe inquiring them on characteristics of their science park.

The second and third study apply a demand-side approach by exploring the perceived benefits of science park tenant firms in relation to science park attributes. It provides insights in attribute-benefit links regarding relevant attributes that science park management can provide to generate specific benefits for tenant firms. A means-end approach, originating from marketing literature, is used to investigate the links. This theory proposes that individuals acquire products not for the product itself, but for what the product can do for them (Ter Hofstede et al., 1998). The results contribute to existing research through not just revealing the important benefits, but also the means to achieve them according to tenants. For the second study, an a priori defined list of science park facilities and services is presented to science park tenant firms in the Netherlands through an online survey. Tenant firms associate these facility and service attributes with an a priori defined list of perceived benefits. Furthermore, a cluster analysis is performed to classify the tenant firms in different groups based on organisational characteristics. These tenant types allow for the further investigation of whether perceived benefits differ between the tenant types. The third study expands on the scope of the attributes of the second study. In the third study, which is based on another data collection, expands the exploration of the impact of the science park attributes beyond the facilities and services domain.

The attributes in this study are related to proximity towards certain actors, real estate and managerial aspects of the science park. The possible perceived benefits consist of economic, innovation and networking performance indicators. Graphical overviews are made for the most important benefits and the means per attribute group to achieve these benefits.

The fourth study adopts a stated preference approach, also known as stated choice experiment, to model the trade-offs made by technology-based firms (i.e., preferences related to design-related science park attributes). The possible utility differences related to the science park attributes between on- and off-park technology-based firms are investigated. The use of a control group has some advantages. On the one hand it limits to some degree the selection bias, that arises from the fact that a science park tenant already has some motivation to select a science park location in the first place (Siegel et al., 2003a; Vásquez-Urriago et al., 2016). On the other hand, it allows for the investigation of the policy effectiveness of science parks from the perspective of the tenant firms. The stated choice approach is commonly used in travel-behaviour research and other areas of consumer research and allows, in this case, to measure the preferences of firms based on hypothetical science park configurations controlled by the researcher (Hensher et al., 2015). This enables the exploration and experimentation of a wide range of types and serves as an advantage compared to evaluating existing science parks as their configurations are as-is. Within this study, the focus lies on preferences among a heterogeneous group of decision-makers from technology-based firms located on different locations, within various business development phases, technology domains and firm ages in the Netherlands.

1.4. Outline chapters

The four different sub studies form the core of this dissertation and the research structure of this work is visualised in Figure 3. The subsequent chapter 2 is the introductory literature review, which covers a general introduction of the emergence of the science park concept and the role of the science park as a policy and an innovation tool.

The separate sub studies are covered in chapters 3 to 6, which contain a research-specific introduction, literature review, methods section, results and lastly discussion. In chapter 3, four themes of the science park concept are reviewed that could describe and distinguish these locations more adequately. These themes are operationalised to identify clusters that form the science park typology consisting of data from 82 European science park-like locations. Among these themes, a list of facilities and services are extracted for the subsequent chapter 4 and potential benefits as result of these facilities and services are discussed. Moreover, these facilities/services and benefits are presented to a sample of 103 science park tenant firms in the Netherlands and the participating managers of these firms are asked which associations they make between important attributes and benefits.

In chapter 5, proximity, real estate and managerial attributes that might be important for science park tenant firms are examined. Here, the perceived benefits of these science park attributes are explored. Furthermore, existing science park evaluation research is discussed to form an overview of the impact that science parks might have on its tenants.

These attributes and indicators serve as input for the exploration of the associations between perceived benefits (i.e., performance indicators) and proximity, real estate and managerial attributes made by a sample of 51 science park tenant firms in the Netherlands.
In order to study the trade-offs that technology-based firms make, the main drivers that impact location choice are discussed in chapter 6. These location drivers are used to operationalise the experimental design of the stated choice experiment. Moreover, the stated location choice framework of discrete choice data of 69 technology-based firms that participated in this study is also presented in this chapter. Finally, chapter 7 consists of an integral conclusion and the theoretical and practical implications.

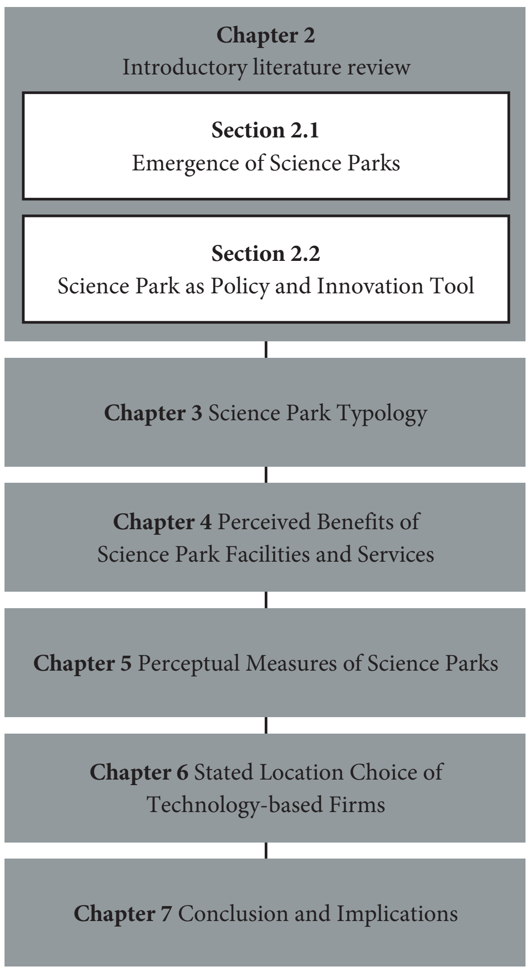


Figure 3 Structure and overview chapters

PART II

Introduction to Science Parks

CHAPTER TWO

Introductory Literature Review

This chapter serves as an introductory literature review on the science park concept. The main purpose of this chapter is to provide a general introduction to the emergence of science parks from a historical perspective and which role the science park could play for policy-makers and firms. In section 2.3, a brief conclusion will summarise the main findings and reveal the different directions of the separate literature reviews of subsequent chapters.

2.1. Emergence of science parks

As a result of diminishing governmental funding and a changing economy in the 1950s, American universities were looking for new opportunities to link universities, industry and government through research. This led to the establishment of the first so-called research parks within university grounds (Saxenian, 1996). This first research park, named Stanford Research Park, is located in California and was the precursor for today's Silicon Valley region. Other early US-based university-related research parks include Research Triangle Park (North Carolina) and University City Science Center (Philadelphia) (Hobbs et al., 2018). With a considerable time lag after the success stories of Stanford Research Park, science parks, such as Cambridge Science Park in the UK and Sophia Antipolis in France began development in the late 1960s (Storey and Tether, 1998). Subsequently, in the 1970s plans are set in motion for the first city-style science park focused on scientific discovery in Japan (Anttiroiko, 2004). On the European side, in 1980s the science park phenomena became a relevant regional development policy tool and science parks grew significantly in numbers (Storey and Tether, 1998). Around the same time, the Taiwanese government funded its first science park (i.e., Hsinchu Science Park) in order to attract technology-based firms and form local industrial clusters (Chen et al., 2006). During the turn of the century, science parks were established in the remaining regions such as Latin America, Africa, the Middle East and other parts of Asia (Rodríguez-Pose and Hardy, 2014).

Within this time period, three major generations of science parks were distinguished by Annerstedt (2006) with each generation having among others its own features in mode of innovation, initiator, governance structure, aim and urban context (see Table 1). The modes of innovation on science parks has transitioned from science push, to market pull and lastly to an interactive and networked innovation process. The participation from local and central governments has also expanded from the initial university-led science parks towards public-private partnerships (Bigliardi et al., 2006). This introduced more complex triple helix partnerships including university, industry and governmental parties for the governance of these parks (Etzkowitz and Zhou, 2017).

Over the generations, the primary objective of science parks has shifted from attaining economic goals of the university and rejuvenation of industrial areas, to the creation and support of the growth of new technology-based firms, and more recently to community-oriented goals for the different stakeholders. Lastly, in terms of the urban context, newer science parks have been developed not necessarily near a university, but located in the more vibrant urbanised areas.

Table 1 Three generations of science parks (Annerstedt, 2006)

Features	First generation	Second generation	Third generation
Mode of innovation	Science push – Linear approach (academic results as input for innovative activities of the industry).	Market and demand pull – science-economy interaction (more focus on the later phases of the innovation process).	Interactive innovation – network orientated from university-industry-government relationships.
Initiator	Universities.	Mainly firms.	Joint effort of university, industry and government
Governance structure	University created organisation.	Privately owned firm responsible for park management.	Professionals experienced in innovation support in public-private-partnerships.
Aim	Strengthen broader economic goals of the university and vitalise the surrounding business community.	The creation and growth of new innovation-related firms.	Increase the wealth of the community through enforcing university-industry-government relations.
Urban context	Specific suburban area in proximity of the university.	Specific area not necessarily in proximity of the university.	Vital urban setting.

The emergence of the science park also saw the creation of regional and global associations of science parks. These organisations are networking organisations with science park managers as members that allow for sharing knowledge and lessons learned within practice. In empiric literature the definitions provided by the American, British and international science park associations are often used. The associations are Association of University Research Parks (AURP), United Kingdom Science Park Association (UKSPA) and International Association of Science Parks and Areas of Innovation (IASP). Some European countries also have their own association dedicated to science parks (e.g., Spain, Italy, France and Sweden). The three most commonly used definitions are discussed here in greater detail.

The AURP defines a university research park as a physical place with the following attributes. A university research park creates, attracts and offers space for science and technology-based firms, and talent. Other organisations include financing research institutes such as universities, public, private and/or governmental research laboratories. A university research park should facilitate the knowledge flow within the park among organisations, but also with organisations in the region (AURP, 2018).

The UKSPA states that a science park is a business support and technology transfer initiative that encourages and supports the start-up and incubation of innovation-led, high-growth, knowledge-based businesses. It provides an environment where larger and international businesses can develop specific and close interactions with a particular centre of knowledge creation for their mutual benefit. A science park has formal and operational links with centres of knowledge creation such as universities, higher education institutes and research organisations (UKSPA, 2016).

The International Association of Science Parks and Areas of Innovation (IASP) uses the following definition for science park, but adds that it can also be used to describe a technology park, research park or technopole. "A science park 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. A science park 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).

According to the AURP the main difference between a university research park and a technology/industry park is the productive relation among on-park firms and the associated research institutions. At university research parks this relation includes providing learning and labour opportunities for students, sharing of facilities and conducting joint research. Additionally, most university research parks are co-located with a university, which provides facilities for researching, testing, learning, training and most importantly technology transfer offices (AURP, 2013). For the UK it is suggested that all science parks are situated close or at a university to enhance the R&D capabilities of on-park firms (Siegel et al., 2003a). This characteristic is similar to the relation between the higher education institution and firms in the definition by the AURP.

As a result of the highly interchangeable nature of the definitions for science, research or technology park by the three associations it is difficult to produce a clear and integral definition. The ambiguity and interchangeable use of the definitions for science park-related properties is troublesome for the comparison and evaluation of these policy and innovation tools (Shearmur and Doloreux, 2002).

2.2. Science park as policy and innovation tool

Science parks can be regarded as both a policy tool and an innovation tool for firms. Among the policy tools, they belong to the supply-side services that enable networking in areas where this would otherwise not take place (Edler and Georghiou, 2007). Up until the early 1980s science parks were university-driven developments. Following their economic success, governments became the drivers of these developments for the enhancement of economic growth. For policy-makers, science parks play a pivotal role in the development of regions and are one of the aspects of the regional innovation system (Cooke, 2001). From a regional perspective, science parks could play an important role at four levels (Saublens, 2007). 1) Image: science parks function as a visible sign of a 'knowledge region' in attracting other similar local strategies that enhance the growth of high-tech industries. 2) Infrastructure: science parks provide proper conditions and advanced infrastructure for the research-intensive enterprises. Often the close proximity to a university provides a specific social environment for the formal and informal interaction between firms and the university staff and students. 3) Support: science parks facilitate complementary services to aid local firms, such as administrative, management or technological support services. As a result, smaller and medium-sized firms can focus on their core (R&D) activities. 4) Network: science parks are characterised with robust networking effects and high levels of social capital. The science park network is heterogeneous with producers, users and disseminators of knowledge with different backgrounds, disciplines and industries. Social capital at science parks can result in exchange of tacit knowledge, community building and development of advanced human resources (Inomata, 2016).

From the firm's perspective, science parks could serve as a tool to stimulate innovation. Cooke (2001) described innovation as the commercialisation of new knowledge with possible, but not necessarily, involvement of universities. He states that it is "a complex process involving users, producers and various intermediary organisations learning from each other regarding demand and supply capabilities and exchanging both tacit and codified knowledge" (Cooke, 2001; 33). The early versions of science parks are founded upon the linear innovation model. This model assumed a linear process of research conducted by academia, development and diffusion of innovation by markets (Massey et al., 1992; p. 57). In general, the innovation process for development of new products, services or processes consists of four phases with feedback loops and that each phase produces different innovative outputs. For studies on the 'new product development models' see: Utterback (1971), Booz et al., (1982; 12), Wheelwright and Clark (1992; 112), Urban and Hauser (1993), McGrath (1996), Cooper (2001; 130), Dahan and Hauser (2001), Hansen and Birkinshaw (2007) and Katz (2011). These phases are; 1) concept development (addressing needs of customers through technological concepts), 2) design and engineer (creating a profitable product, product or process that meets the needs of customers), 3) prototype development & testing (testing and evaluation in order to secure possible market launch) and 4) market launch (full-scale commercial launch of product, service or process). Outputs range from intellectual property rights on ideas, products, services or processes (patents and licensing) to tangible assets.

Science parks were one of the channels that bridged the innovation gap between academia and commercial markets. Universities were largely focused on 'basic or fundamental research', while science parks were mainly positioned on activities such as 'applied research' and 'experimental development' (Quintas et al., 1992). Among science parks, university-industry links range from access to academic staff, equipment, projects, R&D departments and discussions (Massey et al., 1992; Löfsten and Lindelöf, 2005). In more recent times, firms deploy open innovation strategies which rely on both internal and external R&D capabilities through collaboration between organisations (Chesbrough, 2003). In the knowledge-based economy, the boundaries between the traditional roles of university, government and industry are fading. Similar to the university, the industry is also conducting research and training, often on par with universities (Etzkowitz and Klofsten, 2005).

2.3. Conclusion introductory literature review

In this chapter the introductory literature on science parks is reviewed in order to provide for a general introduction of what science parks are. Science parks are real estate or area developments that house universities, research institutes and a wide array of technology-based firms and service providers. As a result of its worldwide diffusion, there exists a wide range of similar terms related to the science park, while a universal definition has not been met. Moreover, science parks can be seen as both policy and innovation tools for regions and firms respectively. In particular, they aim to contribute to amongst others, networking, innovation and economic activities.

In the subsequent four chapters, the separate sub studies will be discussed. Each chapter will focus in more depth into the specific literature in order to review existing studies specific to each sub study. Moreover, each chapter contains its own sampling of respondents, methodology, data analysis and reflection of the results. The literature containing key science park characteristics that can distinguish science parks more adequately is discussed in section 3.2. The different perceived benefits related to facilities and services attributes (i.e., that which the science park can offer) are found in section 4.2. A further investigation between the link into perceived benefits and a larger range of science park attributes is found in chapter 5. Here, the facilities and services attributes are expanded with other real estate attributes, proximity attributes and managerial attributes (see section 5.2). Both chapter 4 and 5 aim to gain insight in for which benefits tenant firms choose a science park location and through which science park attributes these benefits are attained. Lastly, in section 6.2, the literature on the drivers that influence the location choice of technology-based firms are discussed. These location drivers are the design-related attributes used for the estimation of the trade-offs technology-based firms make within relocation decisions.

PART III

Empirical Findings

CHAPTER THREE

Science Park Typology

This chapter is based on:

Ng, W. K. B., Appel - Meulenbroek, H. A. J. A., Cloodt, M. M. A. H., Arentze, T. A. (2019a). Towards a Segmentation of Science Parks: A Typology Study on Science Parks in Europe. *Research Policy* 48 (3), 719–732. https://doi.org/10.1016/j.respol.2018.11.004.

3.1. Introduction

Among innovation policies, science parks belong to the traditional supply-side instruments that facilitate networking among actors (Edler and Georghiou, 2007). Science parks 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 science park 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 and technology park have been used interchangeably in prior science park 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 US, science park 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 science parks 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 science park types. Link and Link (2003) concluded that there are mainly three categories of science parks in the US: 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 science park segmentation either by regional policy on technology transfer or science park 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 science parks studied so far, these prior studies seem insufficient for recognising science park types. Moreover, the focal objective of these past 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 study is: "*What are the main characteristics of science parks and which science park types can be distinguished?*" The need for a comprehensive science park 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 science parks 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 science park 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, science park development involves risk and capital and it is therefore essential not to take one generic science park model for granted, but further investigate the science park concept for better decision-making (Morlacchi and Martin, 2009). Also, because a clear and shared segmentation of science parks is absent, discussion on science park performance remains difficult (National Research Council, 2009; Ferrara et al., 2015). Although some specific science park cases prove to be effective in enhancing the performance of tenants, the conditions that result in successful science parks 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 science park models (Siegel et al., 2003b; Saublens, 2007; Capello and Morrison, 2009), and it makes evaluation of science park performance less complex (Lamperti et al., 2017). Empirical proof of different science park schemes could also provide practitioners with useful insight in the adequate design, development, operation, and evaluation of science parks. This study adopts an empirical and inductive approach towards the science park 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 science park types based on their distinguishing characteristics in practice.

To answer the research question, first relevant science park characteristics from prior research are inventoried (literature review section 3.2). Then data is collected on science park characteristics through a survey among European science park managers (section 3.3) and a cluster analysis is performed based on the (dis)similar science park characteristics to produce a segmentation (section 3.4). The main results are discussed in section 3.5. Lastly in section 3.6, conclusions, limitation and directions for future research are considered.

3.2. Literature review – science park themes

Existing empiric research on firm performance yielded mixed results of science park impact (e.g., Squicciarini, 2008; Albahari et al., 2010; Vásquez-Urriago et al., 2016; Ramírez-Alesón and Fernández-Olmos, 2018). 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). 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 science parks these firms were located at and the effect of heterogeneity among science park types (Ramírez-Alesón and Fernández-Olmos, 2018). 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 science parks, which are grouped in four themes. Following Zhang (2002) knowledge intensiveness and size are discussed, while organisation and location aspects of science parks are added to gain more insight in science park characteristics. Within the following subsections a table is included with the relevant characteristics per theme.

3.2.1. Knowledge intensiveness

The role of the university/higher educational institution is signified as a provider of facilities, services and knowledge for firms at science parks (Löfsten and Lindelöf, 2002). On the other hand, the university could also benefit from the link with a science park, such as increasing publication and patenting activities, more options to acquire skilled scientists and extramural funding (National Research Council, 2009; 16). Moreover, science parks provide short, medium and long-term accommodation for firms in different maturity stages (IASP, 2017). Specifically, science parks are of interest to start-ups, small-medium enterprises, large firms and well-established multinationals alike (Hansson et al., 2005). Science parks can focus on attracting firms from one or more target industries (Squicciarini, 2008; Van Winden and Carvalho, 2015; Lamperti et al., 2017). Liberati et al. (2016) grouped science parks 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 science parks in two groups focussing either on just high-technology firms or on firms with a focus on a specific technology or sector, such as 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 science parks (Shearmur and Doloreux, 2000). In Table 2 the four science park characteristics regarding 'knowledge intensiveness' are listed.

Table 2 Science park characteristics: 'knowledge intensiveness'

Name	Levels	Source
higher educational institution (dichotomous)	Presence of a university and/ or other higher educational institutions.	(Löfsten and Lindelöf, 2002; Link and Link, 2003; Albahari et al., 2017)
Research institutes (dichotomous)	Presence of a public (non-educational) and/or private research institutes.	(Capello and Morrison, 2009; Lamperti et al., 2017)
small-medium enterprise and/or multinational corporations (dichotomous)	Presence of small medium enterprises and/or multinational corporations.	(Hansson, 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)

3.2.2. Size

The style of a science park has been suggested by Zhang (2002) to be one of the distinguishing characteristics: small - centre/incubator with a high building density, medium - park/campus with a low building density and large - with the science park as a city/region. It follows, that these science park styles are related to the total surface area, number of organisations and facilities and services that the science park can provide. Generally, the mix of buildings on science parks 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 science parks 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, science park size was argued by science park 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 3).

Table 3 Science park 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)

3.2.3. Organisation

Science parks have existed and evolved through the decades from early university-initiatives to joint partnerships between university, industry and governments, i.e., triple helix (Annerstedt, 2006). Massey et al. (1992) and Albahari et al. (2017) distinguished technology parks and science parks on the lack of formal relationships or shareholding with a university, which shows that science park 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 science park. These goals can be partly met through, if present, the science park 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 science park management is promoting networking in- and outside the park and enhancing community building on–park (Capello and Morrison, 2009; Van Winden et al., 2015). The long history of science parks has resulted in some research into the age of science parks. Link and Link (2003) found that incubators were less likely to be present at older American science parks. Younger Finnish science parks were more focused on a few technology sectors than their older counterparts (Squicciarini, 2008). While Lamperti et al. (2015) found that firm growth and innovative output of tenants on older Italian science parks was lower, which could be explained through the recent policy interest and funding towards science parks in Italy. For this theme ownership structure, management function and age of the science park are listed in Table 4.

Table 4 Science park characteristics: 'organisation'

Name	Levels	Source
Ownership structure (categorical)	Science park ownership: university, public, private, university-public, triple helix (partnership between university-government-industry), university-private, or public-private.	(Siegel et al., 2003a; Dabrowska, 2016; Albahari et al., 2017)
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 science park (continuous)	Years since establishment of the science park.	(Link and Link, 2003; Squicciarini, 2008; Lamperti et al., 2017)

3.2.4. *Location*

The urban context of science parks can be viewed as the relation between science park and city which can be distinguished in five ways: 1) city as the science park, 2) city contains the science park, 3) city overlaps with the science park, 4) city touches the science park and 5) city is disjointed from science park (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 science park should at least accommodate one incubator or research institution. Besides that, the main offering of a science park 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 science parks 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 science park. 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 science parks, 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 science parks provide, enable especially smaller firms to focus on their core activities (Aaboen, 2009; Dabrowska, 2016). In Table 5 the ten location characteristics are found.

Table 5 Science park characteristics: 'location'

Name	Levels	Source
Urban context (categorical)	1) City contains the location (there are no clear boundaries between the science park and the urban fabric), 2) location overlaps the city (on some areas the science park is integrated within the city), 3) location touches the city (the science park and the city is bounded by for instance a highway), 4) location is disjointed from the city (the science park is completely detached from the urban fabric), or 5) the science park is located on multiple locations (with clear distinction between science parks).	(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; Ratinho and Henriques, 2010; Sanz and Monasterio, 2012)
Presence of leisure facilities (dichotomous)	Cinemas, hotels, sport centres and sports grounds.	
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.	
Presence of services (dichotomous)	Accounting, administrative services, consultancy, graphical design, information access, management support, marketing, hosting networking events, training and venture capital access.	
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)

3.3. Sampling and methods

3.3.1. Sampling procedure

The various science park characteristics of the four themes formed the input for an online survey consisting of 25 English questions for European science park 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 science parks 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 science parks was attained through several online sources, such as from prior reports, member lists of (inter)national science park associations and science park references in empiric literature. Through cross-referencing among (inter)national lists and references a long list was produced of European science parks. 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 International Association of Science Parks and Innovation Areas. In addition, member lists of national science park associations in Europe were examined. By no means was this attempt conclusive for finding all science parks in Europe. This method provided for a substantial list of 675 science park locations across 27 countries in Europe. The list of European science parks formed the total population of this study. Science park representatives of all 675 locations were contacted through an initial email with a link to the web survey with three follow-up reminders.

3.3.2. Methods – 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 science park characteristics i.e., proposed clustering variables were measured on different scales: continuous (e.g., surface area), ordinal (e.g., mix of facilities), 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, 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 hierarchical clustering or k-means 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.

3.4. Results

3.4.1. Sample description

Table 6 shows the total population among 27 countries and the respective response of 82 science parks. Based on the United Nations segmentation into north, east, south and west Europe, the sample of science parks used in this study is representative for the science park population as a whole, as no significant differences were found between the regional distribution of the science park population and the science parks within the sample with $\chi^2(3) = 4.28$ $p = 0.23$. Table 6 shows that within the science park sample only Eastern European countries are underrepresented. Even after multiple reminders, the response rate was only 12%, which was possibly caused by the vast amount of emails that science park management receives daily. Moreover, the relatively higher response rates of Northern, Southern and Western European countries were probably due to respondents having a higher English proficiency (European Commission, 2012).

Table 6 Number of science parks per country in Europe

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			

3.4.2. 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 0.3 and 0.592 (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 Table 7 – 10.

Table 7 'Knowledge intensiveness' variables with frequencies

Variables	Value	$n = 82$
Presence of Higher educational institution (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

Table 8 'Size' variables with frequencies

Variables	Value	$n = 82$
Site surface area (continuous)	(m^2) min 80 - max 5,300,000 Standard deviation 758,700	Mean 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

Table 9 'Organisation' variables with frequencies

Variables	Value	$n = 82$
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 Standard deviation 9.3	Mean 14.5

Table 10 'Location' variables with frequencies

Variables	Value	$n = 82$
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	Mode 4
Mix of leisure facilities (ordinal)	min 0 - max 4	Mode 0
Mix of other facilities (ordinal)	min 0 - max 9	Mode 2
Mix of services (ordinal)	min 0 - max 11	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

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 0.3, 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 Table 11 predictor values are listed for cluster memberships of 22 auto-clustered solutions.

Table 11 Predictor values for cluster membership of all variables

			Knowledge			Size			Organisation				Location								
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	Urban context	Mix of leisure facilities	Mix of other facilities	Mix of services	Laboratory	Incubator	Clean room	Pilot room	Manufacturing space
1a	0.4	45 - 37	.95	1			.22		.09					.25	.09		.15				
1b	0.3	37 - 25 - 20	.95	1			.31		.18					.33	.26		.59				
1c	0.2	20 - 19 - 19 - 13 - 11	.65	.83			.26		.41					.42	.56		1				
2	0.4	47 - 35	.83	1		.49		.20	.10							.16					.02
3	0.4	45 - 37	.95	1		.35	.22		.09					.25			.15				
4	0.4	54 - 28	1	.32		.11	.10			.05				.08			.06				
5	0.4	46 - 36	.84	1		.36	.20				.08			.27			.15				
6	0.4	45 - 37	.86	.91		1	.41					.19		.34			.11				
7	0.4	45 - 37	.95	1			.22		.09					.25	.09			.06			
8	0.4	45 - 37	1	.83			.19		.06					.25	.11				.14		
9	0.4	45 - 37	.95	1			.22		.09					.25	.09					.03	
10	0.3	24 - 23 - 21 - 14	.7				.12		.34	.35							.52		1	.92	

Table 11 (continued)

			Knowledge				Size			Organisation			Location								
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	Urban context	Mix of leisure facilities	Mix of other facilities	Mix of services	Laboratory	Incubator	Clean room	Pilot room	Manufacturing space
11	0.3	30 - 28 - 24			.13			.06	.07	.21							.40		1	.46	
12	0.3	68 - 14	.15					.39			.59			1	.75		.99		.88		
13	0.3	68 - 14			.13			.39			.59			1	.75		.99		.8		
14	0.3	67 - 15			.12		.10				.48			.84	.62		1		.87		
15	0.3	59 - 23	.10				.03				.18			.25	.21		1		.4		
16	0.3	62 - 20	.46				.08				.40			.56	.6	.12	1				
17	0.3	46 - 36	1				.12			.13			.12			.09		.17			.29
18	0.3	42 - 40	.21				.02			.05			.09				.04	.01			1
19	0.3	48 - 34		.31		1	.22			.03	.09						.23		.14		
20	0.3	48 - 34	.86	.78		1	.47	.15	.26								.17				
21	0.3	41 - 41	.95	1		.62	.33					.24		.72					.28		
22	0.3	70 - 12		.26			.12				.37			1	.67		.67		.57		

Each row describes one of the 22 cluster solutions 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 0.3 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.

The seven variables selected for clustering were: 'presence of higher educational institutions', 'presence of research institutes', 'surface area site', 'ownership structure', 'mix of leisure facilities', mix of other facilities' and 'laboratory'. 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 in the clusters and the comparison between six and seven cluster solutions did not show vastly superior six-cluster solutions. 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 relatively high compared to other cohesive solutions. Correlations between these clustering variables were relatively low with none exceeding 0.6 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.

3.4.3. Cluster solutions

Initial auto-clustering of the Twostep cluster analysis with the BIC produced a 2-cluster solution with a silhouette coefficient of 0.4. Table 12 shows the 2-cluster solution selected by the algorithm, because it had the lowest BIC value (1,304.481) and highest ratio of distance measure (1.610), indicating significant different subclusters. In the case of the AIC, the 5-cluster solution was selected (1,062.005) as the lowest AIC value paired with the highest ratio of distance measure (1.513).

Table 12 Output auto-clustering AIC and BIC science park types

# of Clusters	Akaike Information Criterion	AIC Change	Ratio of AIC Changes	Schwarz Bayesian Criterion	BIC Change	Ratio of BIC Changes	Ratio of Distance Measures	Silhouette coefficient
1	1,306.417			1,366.585				
2[b]	1,184.145	-122.272	1.000	1,304.481	-62.104	1.000	1.610	0.4
3[c]	1,127.115	-57.031	0.466	1,307.618	3.137	-0.051	1.296	0.3
4	1,094.497	-32.617	0.267	1,335.169	27.551	-0.444	1.002	0.3
5[a]	1,062.005	-32.492	0.266	1,362.845	27.676	-0.446	1.513	0.2
6	1,057.489	-4.516	0.037	1,418.497	55.652	-0.896	1.099	0.2
7	1,057.867	0.378	-0.003	1,479.043	60.546	-0.975	1.127	0.2

Note. a. Auto selected five cluster solution through the AIC.
b. Auto selected two cluster solution through the BIC.
c. Manual selection three cluster solution.

Further investigation of the predictor importance showed that the variables 'presence of research institutes' and 'presence of higher educational institutions' 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 Table 13 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.

Table 13 Comparison science park cluster solutions

C	*n*	%	id cases of 3-cluster solution (*n*=82)																			
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			
C	*n*	%	id cases of 5-cluster solution (*n*=82)																			
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	

To describe the results, in Table 14 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.

Table 14 Cluster comparison of 3-cluster science park 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 higher educational institutions	54	66			20	100%	25	100%	9	24%	0.95
Laboratory present	42	51			18	90%	6	24%	18	49%	
Shared laboratory present	28	34			0	0%	19	76%	9	24%	0.59
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 1,000 m²)			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											
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%	0.18
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%	

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 higher educational institutions (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 higher educational institutions (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).
- ❖ Cluster 3 (*n* = 37/82). Small 'incubator locations', publicly owned (38%), research and higher educational institutions 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.

3.4.4. 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 science park 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 (1 = yes and 0 = no). 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 15 shows 17 dichotomous variables that contained significant differences between clusters. Significant levels were identified both on the 0.05 and the 0.001 level (2-tailed). The Fisher Exact-test was used to reveal the significant differences for the variables 'small-medium enterprises', '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 2x2 tables. Other significant differences were tested with chi-square tests.

Table 15 Variables showing significant differences between clusters of science parks

	Variables	Science parks		
		Research (20)	Cooperative (25)	Incubator (37)
K	Small-medium enterprises 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
S	Multiple building location	*17	*20	**14
	Number of resident organisations			
	Less than 50 organisations	5	*3	**21
	More than 100 organisations	8	*16	*11
L	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

Note. Significant on $p = 0.05$* or 0.001** level (2-tailed).

The first cluster 'research locations' was the least times significantly different on attribute variables. Cases within this cluster tended to consist of *multiple buildings* ($\chi^2 = 5.85$; $p = 0.016$). Services in terms of 'consultancy' ($\chi^2 = 11.99$; $p = 0.001$) and 'venture capital' ($\chi^2 = 6.14$; $p = 0.024$) 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 science parks in this cluster were active in 'energy-related technologies' ($\chi^2 = 4.023$; $p = 0.045$) as societal challenges are gaining attention from knowledge-intensive organisations (OECD, 2015a). 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' ($\chi^2 = 4.85$; $p = 0.028$) and provided space for 'more than 100 resident organisations' ($\chi^2 = 6.68$; $p = 0.010$). In contrast, cases with 'less than 50 resident organisations' were uncommon in this cluster ($\chi^2 = 8.59$; $p = 0.003$). For the large number of leisure facilities, significant differences were found at 'sport centres' ($\chi^2 = 16.76$; $p = 0.000$) and 'sports grounds' ($\chi^2 = 20.16$; $p = 0.000$). For other facilities that were more common, this was the case for 'banking' ($\chi^2 = 14.24$; $p = 0.000$), 'child care' ($\chi^2 = 21.12$; $p = 0.000$), 'medical' ($\chi^2 = 8.76$; $p = 0.003$) and 'shops (food)' ($\chi^2 = 8.50$; $p = 0.004$). 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' ($\chi^2 = 17.01$; $p = 0.000$), provided space for a smaller number of firms ($\chi^2 = 13.50$; $p = 0.000$) and mainly small-medium enterprises (Fisher's Exact-test $p = 0.005$). Furthermore, leisure facilities, such as 'hotels' (Fisher's Exact-test $p = 0.004$), 'sport centres' ($\chi^2 = 14.08$; $p = 0.000$) and 'sports grounds' ($\chi^2 = 8.81$; $p = 0.003$) were found significantly less at this type of locations. In addition, the cases with 'banking' ($\chi^2 = 10.77$; $p = 0.001$), 'child care' ($\chi^2 = 10.81$; p = 0.001), 'residential housing' (Fisher's Exact-test $p = 0.044$) and 'shops (food)' ($\chi^2 = 9.07$; $p = 0.003$) were significantly less common. Last, the large number of 'consultancy' services were found significant ($\chi^2 = 7.75$; $p = 0.005$), 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' ($\chi^2 = 4.703$; $p = 0.03$). This is probably a result of their relatively 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, 2015a). The characteristics of incubator locations, such as the small size, absence of research institutes and higher educational institutions, 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.

3.5. Discussion

Although the four themes are interrelated the findings on each aspect will be discussed separately. In terms of 'knowledge intensiveness', in line with Zhang (2002) this study showed that the two most important clustering variables measured the knowledge intensiveness of cases through the 'presence of research institutes' and 'higher educational institutions'. Compared to the two other science park types incubator locations were relatively less knowledge-intensive as these locations housed less research institutes and higher educational institutions. Moreover, the theme 'size' was also considered by Zhang (2002) through 'style' (e.g., single building/incubator, park-style). The 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 science parks Link and Link (2003) and Albahari et al. (2017) distinguished parks on the degree of university ownership (all university-related ownership models - i.e., university, university-public, triple helix and university-private). The current 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 science park types. The relation between cluster membership (categorical) and university-related ownership models (dichotomous) was not found significant ($\chi^2 = 1.27$; $p = 0.529$). In contrast to some previous research which focused on technology sectors covered by science parks (e.g., Squicciarini, 2008, Liberati et al., 2016), no significant differences were found between science park types with regard to this attribute. There is little evidence found on specific sectors within the 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 science park 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 science parks the (dis)similarities of distinct park types were studied. These insights could be used as input for explaining differences in firm performances. As science park impact was not inquired three cases within the sample will be highlighted as examples. One of the cases classified as 'incubator location' was Lispolis as at this science park 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 science parks, i.e., job, revenue of tenants (Ratinho and Henriques, 2010). The British Surrey Research Park 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, such as increased technology transfer between university and markets, reputation, the creation and growth of new firms (Parry, 2014). Within the cluster solution this science park 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 in the Netherlands 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 science parks are one of the components of an ecosystem the mixed science park 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 science park types could further aid researchers in tackling the issue of heterogeneity among science park cases. The outcome of this work complements and builds upon recent studies on heterogeneity among science park characteristics of Fukugawa (2013) and Liberati et al. (2016). This study showed that when considering 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 science park types. Therefore, the introduction of these homogenous science park types could aid past and future researchers in comparing and evaluating science parks or tenant firms more adequately. To conclude, the unique features and (dis)similarities among the three cluster solutions are summarised in Table 16. Empty cells denote that no significant differences were found.

Table 16 Summary of (dis)similarities of the three science park cluster solutions

	Variables	Research locations	Cooperative locations	Incubator locations
K	Research institutes	Present	Present	Absent
	Higher educational institutions	Present	Present	Absent
	Small-medium enterprises/ multinationals			Small-medium enterprises present / multinationals absent
	Air, space and land transportation technologies			Absent
	Energy-related technologies	Present		
S	Site surface area	Medium	Large	Small
	Single or multiple buildings	Multiple	Multiple	Single
	Number of resident organisations		Larger number	Smaller number
O	Ownership	Public-private	Public-private/Public	Public
L	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		

3.6. Conclusions and limitations

In the past decades the majority of academic research in this area has focused on science park 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 science park 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 science park resident organisations were a result of neglecting the features of the science park itself, i.e., the structures providing space and services for these residents (e.g., Siegel et al., 2003a; Capello and Morrison, 2009). It is therefore argued that before academics can evaluate the performance of science park resident organisations ('what they do'), more attention is needed for the structures that house these organisations ('what they are'). This study fills this knowledge gap by introducing descriptions of three distinct science park types that could make comparing firm performance and benchmarking science parks more useful and appropriate. The three science park 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 science park characteristics. The key contribution of this study to the existing broad science park literature is that a method is presented that combines previous characteristics of classifying attempts and produces three statistically sound science park types. Previous efforts are characterised by their qualitative nature and limited number of distinguishing variables, therefore only studying certain aspects of the science park 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., 2017). However, within the three science park types this was not the case, which reveals that ownership of science parks has become more diverse including public and/or private science park owners. The cluster analysis showed that ownership structure was the least important variable to distinguish distinct types. Also, no significant differences were found between science park 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 science parks focused on the biotechnology and life sciences sector. On the other hand, incubators are present at almost all cases, which implies that (new) science parks should at least consider providing these facilities.

Based on the findings a refinement is proposed for the science park definition of the International Association of Science Parks and Innovation Areas (IASP). IASP defined a science park as: "…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).

This definition is used most often by academia and practitioners and is considered by the former to be broad due to its application to a large number of science park-related objects. This study revealed what a science park could 'be', while the association's definition described what it should 'do'. In accordance to the IASP definition, science parks 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, the facilities and services that were most distinguishing within the European context are revealed. Laboratories, leisure and support facilities and business development services (i.e., consultancy and venture capital services) were relative important to discern science park types. A more comprehensive description of the three science park forms that aids as a supplement to IASP definition is formulated as follows.

'A science park is a real estate or area development, managed by an on-site management company. It is home to knowledge organisations, such as research institutes, higher educational institutions 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 science park typology consisting of incubator locations, research locations and cooperative locations can be distinguished.'

This study has several managerial implications: it offers a general overview of the current state of the European science park context and characteristics. Moreover, the outline of the three science park types provides public entities insight in evaluating future investment alternatives. It gives potential investors means to explore various science park types they want to invest in. For resident organisations seeking bases for operations the science park typology presents distinct descriptions to compare alternative locations. In addition, characterisation of these science park types provides current science park managers/owners with a better understanding of what makes their science parks distinct. The various science park types and their distinguishing characteristics can be used to market science park locations more effectively. Furthermore, it gives science park managers valuable insights for seeking similar locations as suitable competitors for benchmarking purposes. Moreover, the 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). The findings contribute to this call for heterogeneity, by offering an overview of the current state of the European science park context.

Such an overview provides policy-makers with relevant preliminary insights as it is reasoned that different science park types have a distinct effect on innovative performance (Albahari et al., 2017) 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 science park research, the sample was small compared to the total European science park population. Additionally, the majority of the science parks within the sample were established within the Netherlands and the United Kingdom, while other typical science park countries, such as France and Germany were less represented. As Eastern European countries were underrepresented in the 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 the exploratory segmentation of science parks the national innovation system per country was not considered, which science parks are an integral part of. Future multinational studies with larger sample sizes of science parks could consider 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., 2013). Due to the limited number of science parks per country this sample did not reflect the diversity of economic development among different national innovation systems (Nelson, 1993). The European science park sample limits the international generalisability of the research findings. As science parks are spread globally, the question arises whether similar or other types emerge in other strong science park regions such as North America and Asia. Moreover, this exploratory study is one of the first to propose a science park 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 higher educational institutions 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 science park (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 science park segmentation could include the investigation of ecosystems types that have developed and the policy success of the creation of business ecosystems.

An outline is produced of the various science park forms, contributing to the further empiric conceptualisation of the science park. The academic debate is advanced through what a science park could be, while future research can focus on the relation between science park types and firm or science park performance opening new venues of policy evaluation. Another possible venue for further exploration includes the needs of science park 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 science park, 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 science park styles distinct, i.e., future research is required for the impact of science park 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 science park types to evaluate differences among science park cases and this could result in different firm performances.

CHAPTER FOUR

Perceived Benefits of Science Park Facilities and Services

This chapter is based on:

Ng, W. K. B., Junker, T. R., Appel - Meulenbroek, H. A. J. A., Cloodt, M. M. A. H., Arentze, T. A. (2019b) Perceived Benefits of Science Park Attributes among Park Tenants in the Netherlands. *The Journal of Technology Transfer*. https://doi.org/10.1007/s10961-019-09744-x.

4.1. Introduction

Science parks are commonly described as physical areas where multiple knowledge-intensive organisations and institutes co-locate and where innovation is formally and informally leveraged (Link and Scott, 2015). Through decades of science park development their main mission varies from fostering collaboration between university and industry, to regional development and ultimately increasing the efficiency of innovation (Bigliardi et al., 2006). From a policy perspective, science parks are supply-driven measures that aim to improve networking and collaboration between park tenants (Edler and Georghiou, 2007). On macro-level, they mainly address market failures in terms of encouraging R&D to take place at selected locations (Appold, 2004). On micro-level, hosted firms share facilities and services, which allows them to avoid large capital investments in expensive facilities, optimise use and promote synergy (Brinkø et al., 2015; Van Winden et al., 2015). In addition, co-location of various firms and, if present, universities provide for proximity benefits, such as knowledge sharing between tenants (National Research Council, 2009; Ferrara et al., 2015).

Although science parks have captivated the attention of academia for decades, the body of knowledge on the concept remains embryonic and most of the empirical work has a limited geographical scope by focusing primarily on the UK and China (Hobbs et al., 2017). Existing science park research has mainly focused on the evaluation of the impact of science parks on firms in order to prove their policy effectiveness, but with limited conclusive evidence. Only uniform evidence of increased networking and collaboration between firms has been found, while little evidence is found for increased economic output (Albahari et al., 2010). According to Mora-Valentín et al. (2019) the current conceptual framework of science parks allows for more research to be done in the development of science parks.

Strikingly, little science park research is aimed at the needs of tenants in terms of the science park facilities and services (Albahari et al., 2018). Van Dierdonck et al. (1991) studied the perceived benefits of Dutch and Belgian science park firms during a period where science parks bridged the gap between academic science and industrial technology.

Westhead and Batstone (1999) explored the perception of managed science parks and concluded that they should strengthen their managerial effort to show that these parks are more than a real estate proposition. From the perspective of university administrators, the perceived impact of science parks on attaining academic missions was studied by Link and Scott (2003). Nowadays, some form of management is present at the majority of science parks in Europe (Ng et al., 2019a). Moreover, the provision of management expertise and potential venture capital show that science parks have further developed beyond real estate (Etzkowitz and Zhou, 2017). Managing the community of firms and shared resources and facilities on science parks is expected to create value on firm- and park-level (Van Der Borgh et al., 2012). Albahari et al., (2018) revealed that configuration and process gaps (i.e., respectively facilities and services) between supply and needs are acknowledged by science park managers as troublesome. This mismatch deviates them from achieving policy goals, affects current tenant firms' performance negatively and repels potential new tenants. As science parks are commonly funded partially by public sources there is a sense of responsibility for proper resource allocation for current and future science park projects (Monck and Peters, 2009). Research into the perception from the user side of science parks is therefore a first step into understanding how science parks create value for their tenants (Albahari et al., 2018). Insights in the perceived value of different facilities and service levels contributes to more effective science parks that in turn could promote the overall performance of the park and its wide range of tenants.

Furthermore, as firms may differ regarding those needs and the science park impact, the diversity of tenants should be considered to obtain a clear insight in the needs of possible subgroups. Previous research suggests that science park impact varies among different types of firms (e.g., Díez-Vial and Fernández-Olmos, 2015; Ubeda et al., 2019). So far, the majority of evaluation research has focused solely on start-ups (e.g., Fukugawa, 2006; Yang et al., 2009; Chan et al., 2010; Löfsten, 2016), although science parks are also home to established firms, research institutes and service providers (Van Der Borgh et al., 2012). Ferguson and Olofsson (2004) revealed that park firms have a wide range of maturity phases, which suggests that different needs are required to induce growth for starting and for more developed firms. For example, smaller and younger firms experienced more benefits from the science park's image and the collaboration with universities than older and larger firms (Ferguson and Olofsson, 2004). Moreover, Chan and Lau (2005) showed that even among start-ups within various business development phases different benefits were important within their incubator program on science parks.

The current study's novel contribution to the science park literature is to provide insight in the associations made by science park tenant firms in the Netherlands between perceived benefits and the provided facilities and services, whilst considering for the possible tenant types. Therefore, the research question addressed in this study is: "*Which benefits do science park tenant firms associate with science park facilities and services and does this perception differ among tenant types?*" The objective of this study is to reveal the associations tenants make between a priori-defined facilities and services and specific science park benefits. It is based on a survey of 103 science park tenants in the Netherlands.

This study adds to the innovation policy management and science park knowledge base both in a scientific and a practical way. For further conceptualisation of the science park, this study sheds light on the link between what a science park offers and what value it brings to the different types of tenant firms. Insights into perceived benefits leads to a better understanding of how science parks impact tenants. For the design and management of science parks, the inclusion of specific facilities and services can be aspects to be considered as means to create value and to affect the overall performance of the science park itself or its tenants.

In order to answer the research question, first the potential benefits are retrieved from literature. Then the research approach is explained in more detail in section 4.3. The sample of science park tenant firms and the analysis of associations between attributes and benefits are examined in section 4.4 and discussed in 4.5. Finally, in section 4.6 the major conclusions and possible future research directions are discussed.

4.2. Literature review – benefits of science park facilities and services

Science parks are composed of facilities and services that are aimed at innovation policy goals (Albahari et al., 2019). That some of these goals are not met due to the misalignment of the science park real estate and services has been coined 'innovation incommensurability' (Etzkowitz and Zhou, 2017). As science parks can be configured in various ways to attain different missions, goals and functions, evaluating them is a complex task (Capello and Morrison, 2009). Consequently, the present study is focused on the needs of science park users, to reveal which benefits science park tenants associate with the offered facilities and services. These perceived benefits could complement traditional performance measures as these indicators might not apply to all science park firms (Leclusyse et al., 2019). The following sections review the literature to provide an overview of the benefits tenant firms might perceive. Each of the seven subsections consist of one perceived benefit: 1) knowledge sharing and collaboration, 2) proximity of university, 3) proximity of firms in similar sectors, 4) proximity of markets and customers, 5) liveability of the site, 6) image and prestige of the site and 7) cost of accommodation and services.

4.2.1. Knowledge sharing and collaboration

Essentially, science parks are developed to promote interaction or networking through proximity between actors and to promote industrial activity and ultimately innovation (Edler and Georghiou, 2007). The underlying mechanisms of localised knowledge spillovers among co-located firms and institutions are believed to enhance invention and innovation (Lee and O'Huallachain, 2012). In general, geographical proximity contributes to, amongst other, cost reduction, increased personal interaction and development of social networks and therefore it aids knowledge transfer (Rosenkopf and Almeida, 2003). Existing research showed that firms where corporate or academic R&D and high-skilled labour is essential, are more likely to concentrate geographically. Co-location of innovating firms and academia contributes in some way to the circulation of information among those involved (Storper and Venables, 2004). Besides geographical proximity, other types of proximity are likely to influence knowledge transfer between actors as well (Boschma, 2005). These include cognitive, organisational and social proximity, where too much or too little proximity hinders knowledge transfer.

From a social proximity perspective, unplanned knowledge transfer on park-level is characterised by non-pecuniary and informal interactions. Social proximity is largely based on repeated interactions and trust (Boschma, 2005). This is in contrast to knowledge trade, which is often facilitated by technology transfer offices through licensing, spin-offs or contract research (Villasalero, 2014). Moreover, Storper and Venables (2004) argued that sharing difficult to codify, tacit knowledge and the stimulation of innovation is only possible through a high social proximity between actors and the subsequent face-to-face interactions. The degree of interaction (i.e., through face-to-face or virtual contact) and proximity among both parties' knowledge bases is key for the success of knowledge transfer (Cummings and Teng, 2003). Díez-Vial and Fernández-Olmos (2015) argued that repeated formal and informal collaboration with universities allow firms to increase their absorptive capacity. This capacity of identifying value, assimilation and commercialisation of ideas enables organisations to utilise external knowledge sources more efficiently (Cohen and Levinthal, 1990). Firms with high absorptive capacity benefit less from science parks as their knowledge bases might be too similar to others (Ubeda et al., 2019). Tacit knowledge, which is often complex knowledge, is more easily shared among strong ties, while well-documented knowledge is benefited by weak ties (e.g., Hansen, 1999; Byosiere et al., 2010). Socialisation among actors on science parks enhances tie strength and therefore eases the transfer of valuable tacit knowledge (Inomata et al., 2016).

4.2.2. Proximity of university

Dettwiler et al. (2006) inquired start-ups on the importance of geographical proximity benefits, distinguishing nearness to a university, to customers and to firms (both competing and similar types). The proximity of a university was most valued, followed by customers and lastly firms whereby competing and similar firms were equally important. Ferguson and Olofsson (2004) also found that start-ups valued the cooperation with a university relatively more than access to new customers. Industrial R&D activity that is closely located to the university shows on a state-level higher numbers of corporate patents (Jaffe, 1989). On firm-level, Romijn and Albu (2002) showed that start-ups that reported geographical proximity benefits to universities or laboratories tended to have more and/or complex innovations and also a higher number of held patents. Audretsch and Lehmann (2006) argued that small and medium-sized enterprises choose to locate near universities for the potential access to research and human capital. In the US, science parks more closely located to research universities were found to be growing faster in the number of firms, but this was unrelated to the presence of incubators (Link and Link, 2003).

4.2.3. Proximity of firms in similar sectors

Organisational proximity is defined as the similarities in control and management of each involved actors' respective organisation (Boschma, 2005). From an organisational perspective Chan and Lau (2005) argued that as science parks co-locate firms who are active in various parts of the value chain, these firms are likely to find suitable partners for collaboration both downstream and upstream. Science parks and if present incubators, play a pivotal role as intermediaries to reduce uncertainty and promote knowledge transfer for younger firms (Fukugawa, 2013). However, McAdam and McAdam (2008) argued that as firms mature and competition rises, the willingness to share ideas and knowledge and collaborate on problem-solving will likely decrease.

For firms in more matured industries the close proximity for knowledge benefits can be less apparent as knowledge is likely to be more codified and standardised, which limits the need for co-location for sharing tacit knowledge (Díez-Vial and Fernández-Olmos 2017).

From a cognitive proximity perspective, Koçak and Can (2014) revealed that knowledge sharing ties were most commonly followed by joint project or product development ties and that these ties were even more frequent when firms were active in similar industries. Therefore, science parks attempt to select similar firms based on technologies or sectors in order to promote synergy among them (Van Winden et al., 2015). On the one hand, sufficient cognitive proximity between firms contributes to organisational learning (Gilsing et al., 2008). On the other hand, co-location can be disadvantageous as it also leads to knowledge spillovers towards competing firms that are cognitively close to each other (Díez-Vial and Fernández-Olmos, 2017). Therefore, an optimal cognitive distance is required for mutual understanding and innovation (Van Gilsing et al., 2008). The need for a moderate overlap between knowledge bases underscores the need for a mix of organisation types on science parks that results in mutual learning.

4.2.4. Proximity of markets and customers

The geographical proximity of markets and customers provides means for firms to achieve their commercial goals, attain information on market demand and optimise their products or services (Lindelöf and Löfsten, 2003). Capello and Morrisson (2009) argued that interactions with customers should be both stable and intense and could lead to incremental innovations. However, Romijn and Albu (2002) did not find significant innovation benefits through networking activities of young firms with customers. Similarly, firms located on or off science parks that experienced high benefits from proximity of customers also did not show significant different growth rates (Ferguson and Olofsson, 2004). Albahari et al. (2018) suggested that younger firms experience a positive effect of novelty, which attract customers on the short-term, but diminishes over time.

4.2.5. Liveability of the site

According to Kharabsheh (2012) both science park managers and park tenants value the high-quality landscaped environment, facilities and services as means to accommodate their employees and clients. As property initiatives, science parks provide both private space and public space for universities, firms and institutes. The landscaped public area can be vibrant and green with a high level of quality of environment (Zhang, 2002; Wang and Adolphe, 2012). Nature and green are often associated with positive psychological effects for work environments (Oseland, 2009; Jahncke et al., 2011). Recent studies on greenspace at science parks revealed that the use of greenery and seeing greenspaces from indoor workplaces contribute to the wellbeing of employees and alleviate job stress (Gilchrist et al., 2015; Colley et al., 2017).

4.2.6. Image and prestige of the site

Besides liveability, the high-quality landscaped park environment relates to image and reputation benefits of both the science park and its tenants (European Commission, 2013). Especially for start-ups, a science park can provide legitimacy and overcome their role as new entrants (Ferguson and Olofsson 2004). According to Van Dierdonck et al. (1991) only a minority of their responding firms on Dutch and Belgian science parks perceived the access to scientific or technological resources at universities to be the most important location factor. In contrast, image of the site, modes of transportation and financial incentives were the most important for tenant firms to choose a science park. Chan et al. (2010) revealed that firms mainly located on science parks for improving their reputation and image, which is perceived as commercially beneficial, while less for networking or knowledge sharing. However, Ferguson and Olofsson (2004) showed that perceived image benefits alone are insufficient for stimulating growth or survival for start-ups. Furthermore, dedicated facilities and services with shared reception services make them appear more professional (Chan and Lau, 2005; McAdam and McAdam, 2008; Van De Klundert and Van Winden, 2008).

4.2.7. Cost of accommodation and services

Within the park environment, facilities, such as laboratories, meeting rooms, conference rooms and sport facilities are designated for both private use and shared usage among different tenant firms (Ng et al., 2019a). Specifically, for start-ups, specialised R&D facilities, equipment, offices, business support, training programs, networking events, dining facilities, venture capital access are usually part of the shared facilities and services within incubator premises (McAdam and McAdam, 2008). Moreover, the large range of science park facilities and services enable especially start-ups to focus on their core activities (Aaboen, 2009; Dabrowska, 2016). Often, rented facilities and the use of park services that are shared between firms can reduce costs among park firms (Brinkø et al., 2015). However, according to Westhead and Batstone (1999) accommodation costs were named one of the most important disadvantages of science parks and even more so for firms on non-managed parks. They found that while groups valued the offered services and the park image, they were reluctant to pay the premium prices.

In conclusion, on the user-side, the benefits science park tenants see regarding attributes science parks offer as emerged from this literature review, are: 1) knowledge sharing and collaboration, 2) proximity of markets and customers, 3) proximity of university, 4) proximity of firms in similar sectors, 5) liveability of the site, 6) image and prestige of the site and 7) cost of accommodation and services.

On the supply-side, fifteen science park attributes are distinguished, which are adopted from previous research on science park attributes (i.e., Ng et al. 2019a). The list of attributes and benefits that are used in this study are listed in Table 17.

Table 17 Labels science park benefits and attributes (i.e., facilities and services)

Labels	Benefits	
Knowledge	Knowledge sharing and collaboration	
University	Proximity of university	
Firms	Proximity of firms in similar sectors	
Customers	Proximity of markets and customers	
Liveability	Liveability of the site	
Image	Image and prestige of the site	
Cost	Cost of accommodation and services	
Labels	Attributes	Examples
R&D	R&D facilities	Laboratory, clean room, piloting room
Equipment	Equipment	3D printer, autoclave, centrifuge
Specials	Specials	Particle accelerator, wind tunnel, joint permits
Workspace	Workspace	Conference centres, co-working space, meeting rooms
Business support	Business support	ICT support, administrative, consultancy
Training	Training programs	Incubator programs, workshops, lectures
Park management	Park management	Maintenance, cleaning, safety, security
Information	Information access	Library, network platform, databases
Venture capital	Venture capital access	Legal and finance agencies, investment funds
Networking	Networking events	Conferences, symposium, business courses
Social	Social events	Concerts, marathons, food festivals
Dining	Dining facilities	Restaurant, cafeteria
Residential	Residential facilities	Hotel, residential housing
Leisure	Leisure facilities	Cinema, sports facilities, wellness, shops
Additional	Additional facilities	Expat centre, day care, car share service

4.3. Sampling survey and methods

4.3.1. Sampling procedure

An online survey was designed and distributed through management teams of science parks among the decision-makers (i.e., CEO or manager) of park tenants in the Netherlands. As they all are located in the Netherlands, respondent firms were expected to be exposed to similar climate, culture and institutions (Acs et al., 2013). To be eligible for this research, science parks had to meet the following criteria: a physical location with multiple buildings, presence of a research institute or university, a professional management team and shared facilities and services. The management teams of seventeen eligible science park locations were contacted and ultimately seven participated. This top-down approach was chosen as management teams have close contacts with tenants. The survey was distributed between September and November of 2017 among 565 tenant firms that were contacted through their respective science park management.

4.3.2. Survey structure

The first section of the survey involved questions on personal and general organisational information. Specifically, respondents were shown the 'new product development funnel' (NPD), consisting of 1) 'concept development', 2) 'design and engineer', 3) 'prototyping and testing' and 4) 'launch' (Dahan and Hauser, 2002). Each phase was described and respondents were asked which if any of the phases was applicable for their firm. Furthermore, respondents selected one or more of the 21 sectors in which their firm is active. In the second section respondents indicated which of the fifteen predetermined science park attributes were offered on their location. Then, in the final section of the survey, the seven science park benefits were presented (see Table 17).

First, respondents were asked independently from the attributes, which two of the listed science park benefits were most important in choosing their science park location. For the remainder of this chapter, these benefits without being related to specific science park attributes are referred to as principal benefits, as they are important for tenants in a general sense. Then, the fifteen attributes were presented separately and respondents indicated which (if any) benefits they most strongly associate with the presented attribute. This quantitative approach of collecting association data is adapted from the association pattern technique (Ter Hofstede et al., 1998). That technique presents predetermined attributes, benefits and values of a product to consumers and aims to gain insight in their needs. The attributes embody 'what' consumers choose, while benefits that are associated with these attributes are 'why' they chose them (Dellaert et al., 2014).

Moreover, it allows for analysis techniques from association rule learning based on conditional and unconditional probabilities of attributes and benefits (Tan et al., 2006). In this manner, respondents chose a maximum of the two most important benefits that they deemed related to each attribute. When a respondent did not associate any benefit to a specific attribute, the option of 'not applicable' was selected. Therefore, the associations for a specific attribute are established by eight binary variables (seven benefits and the 'not applicable' option).The selection of not more than two benefits enforced prioritisation and relieved pressure for respondents during their completion of the survey by not asking them to rank all benefits each time.

4.3.3. Cluster analysis and association analysis

The analysis was twofold: first the Twostep clustering algorithm was used to distinguish meaningful subtypes of the sample of firms based on organisational characteristics. The technical explanation and considerations regarding the Twostep clustering technique used for this study can be found in section 3.3.2.

The second part of the analysis considered the associations respondents established between the attributes and benefits. In this part, the observations (n) were the associations between attributes and benefits. The fifteen attributes (A) were presented to respondents in order to gauge which if any of the seven benefits (B) were associated with each particular attribute. A 'not applicable' option was included for attributes where no benefits were found relevant by respondents. This approach led to two sets of observations: the selection of relevant attributes and associations of benefits with the selected attributes. These observations allowed for the following three analyses procedures.

First, a chi-square test of goodness of fit was conducted to analyse the associations between attributes and benefits. The inclusion of the 'not applicable' (towards a benefit) option revealed the relevance of the attributes: hence a first test considers whether the selection of the 'not applicable' option is significantly different for the attributes from equal probabilities. Next for the remaining analyses, the 'not applicable' option was excluded in order to focus on the benefit associations. The same test was done for each attribute to find if the observed selection frequencies of seven benefits differed significantly from the expected probability if no associations exist (the marginal probability of each benefit).

Secondly, based on the association data the probability was determined for each B_j separately, that the benefit is mentioned in the context of some attribute, denoted as $P(B_j)$, where j is one of the seven benefits. The probability that B_j is mentioned in the context of a specific attribute A_i, is given by the conditional probability $P(B_j|A_i)$, where i is one of the fifteen attributes. It follows, that if the probability of B_j is not associated with the attribute A_i, the expected ratio (I) between the conditional and unconditional probability is equal to one or lower. Its occurrence probability is the same as the unconditional probability ($I = 1$) or reduces when A_i is given ($I < 1$). A ratio larger than one indicates that B_j is associated with A_i (its occurrence probability increases when A_i is given). The ratio (I) is known as the lift ratio in the marketing and data-mining literature. The lift ratio is more informative than $P(B_j|A_i)$ as the latter does not consider the base probability of B_j and therefore does not reveal attributes and benefits that are not associated (i.e., $I \leq 1$) (Tan et al., 2006). Formally, the lift ratio is defined as:

$$Lift\ ratio\ (I)(A_i \rightarrow B_j) = \frac{P(B_j|A_i)}{P(B_j)} = \frac{P(A_i,B_j)}{P(A_i)P(B_j)} \begin{cases} > 1, if\ A_i\ and\ B_j\ are\ associated \\ \leq 1, if\ A_i\ and\ B_j\ are\ not\ associated. \end{cases} \quad (1)$$

Moreover, the equation of the lift ratio is somewhat similar to the chi-square equation as both calculate the ratio between the observed and the expected values. The lift ratio reveals the strength and the direction of the association between A_i and B_j, while the chi-square value shows if the vector of benefit-associations with the attribute is significantly different from expected values. On attribute level, each A_i could be associated with seven B_j. Therefore, in the chi-square test, each attribute is treated as a vector with six degrees of freedom. Associations of attributes A_i that turn out to be significant are reported and discussed. Lastly, the association of the different clusters of organisation types were further explored. A chi-square test of goodness of fit was conducted to test if the seven benefits are equally associated by the three clusters of tenant types. Then on attribute level, the lift ratios were calculated for each cluster separately and compared to show possible differences among the most associated benefits.

4.4. Results

4.4.1. Sample description

Seven out of the seventeen science parks were willing to distribute the survey among their tenants. In total 103 representatives of tenant firms completed the survey (response rate 18%). The distribution of respondent firms among the seven science parks is not representative as significant differences are found between the sample and the contacted population firms ($\chi^2(6) = 22.93$ $p < 0.001$). The seven science parks included in this data collection are: Automotive Campus (Helmond), Brightlands Chemelot Campus (Sittard-Geleen), High Tech Campus Eindhoven (Eindhoven), Leiden Bio Science Park (Leiden), TU Delft Science Park (Delft), TU/e Campus (Eindhoven) and Water Campus (Leeuwarden). Table 18 summarises the characteristics of the sample. The majority of respondents were either a director or manager of their firm and worked either in general management (53%) or R&D (23%), which shows that the sample indeed consisted mainly of decision-makers active in relevant departments.

In order to check for non-respondent bias, the procedure of Armstrong and Overton (1977) was used. This method compares the first half (in time of completing the survey) with the last half of the respondents on possible similarities among organisational characteristics. It is assumed that the latter group is relatively less interested in completing the survey, which resembles non-respondents more closely. The respondents were divided in two groups and tests of significant differences were conducted with 'size on park', 'firm age', 'duration of stay' and 'high sectoral focus'. The 21 dummy variables of technology sectors were transformed into a continuous variable in order to find a median of 2, which functioned as a cut-off point to split the sample into 64 firms with a 'high sectoral focus' (1 or 2 sectors) and 39 with a 'low sectoral focus' (more than 2). A significant difference was only found on 'firm age' between the two subsamples ($t(103) = 2.649$, $p = 0.009$), the latter being younger than the former, which suggests there is little non-response bias.

Table 18 Characteristics of 103 science park tenant firms

	Mean	SD			
Firm age (years)	26.32	36.78			
Duration of stay on park (years)	7.88	10.53			
	n	%		*n*	%
Size on park (employees)			NPD funnel (phases)*		
Less than 10	50	48.54	Concept development	46	19.28
Between 10 - 50	32	31.07	Design and engineer	56	25.11
Between 50 - 250	13	12.62	Prototyping and testing	54	24.22
More than 250	8	7.77	Launch	48	21.52
	103	100.00	Not applicable	22	9.87
Sectors*			Activity*		
Biotechnology / Life sciences	28	9.69	Technology industries	52	50.49
Industrial / Manufacturing Systems	25	8.65	Scientific research	32	31.07
Software	24	8.30	Manufacturing	31	30.10
IT / Telecommunications	22	7.61	Education and training	25	24.27
Industrial Electronics	20	6.92	Engineering services	23	22.33
Internet Technologies and Services	18	6.23	Value-added services	20	19.42
Computer / Informatics	17	5.88	Trade, sales, marketing and construction	13	12.62
Energy Technology	16	5.54	Corporate office	12	11.65
Environmental Technology	13	4.50	Other	7	6.80
Chemistry	12	4.15			
Nanotechnology	12	4.15			
New Materials	12	4.15			
Consumer Electronics	9	3.11			
Pharmaceuticals	9	3.11			
Off-shore Technology	7	2.42			
Agro-food / Agriculture	6	2.08			
Food Technology	6	2.08			
Optics	6	2.08			
Aeronautics / Aerospace	4	1.38			
Sports Technology	3	1.04			
Other	20	6.92			

Note. *Respondents were allowed multiple options.

4.4.2. Distinguishing organisation types

Based on the sample size of 103, a conservative number of six cluster variables was used. The minimum sample size should equal 2^m, where m is the number of variables to be considered (Formann, 1984). The six chosen cluster variables from Table 18 were 1) 'technology industries', 2) 'trade, sales, marketing and construction', 3) 'NPD funnel', 4) 'size on park', 5) 'scientific research' and 6) 'duration of stay on park'. 'NPD funnel' is a continuous construct derived from the four binary variables of NPD phases (range 0 – 4, average of 1.95 and a standard deviation of 1.46). Cronbach's α for the four binary variables of NPD phases was sufficient reliable with 0.703 for exploratory studies (Chan et al., 2010).

These cluster variables were chosen in order to differentiate tenant types and compare their needs more adequately. 'Duration of stay on park' is opted for clustering over 'firm age' as both variables were correlated (r (103) = 0.284, p = 0.004) and the length of stay was expected to be more impactful on the science park needs than the age of the firm (Liberati et al., 2016). Multiple cluster solutions were generated varying the number of clusters and the final solution was based on the criteria of a relatively high cohesive coefficient and a relatively high value for the weakest predictor.

In Table 19 distance measures are shown for solutions with a varying number of clusters. The auto clustering of the Twostep clustering algorithm resulted in an eight cluster solution based on the AIC criterion and a six cluster solution based on the BIC criterion. In order to avoid many small clusters, the three cluster solution was selected as this solution had the highest ratio of distance measure (1.405) and an equally high silhouette coefficient compared to the other cluster solutions (0.3).

Table 19 Output auto-clustering AIC and BIC of science park tenant firm types

# of Clusters	Akaike's information criterion	AIC Change	Ratio of AIC Changes	Bayesian information criterion	BIC Change	Ratio of BIC Changes	Ratio of Distance Measure	Silhouette coefficient
1	757.144			783.491				
2	654.920	-102.224	1	707.614	-75.877	1	1.157	0.3
3[c]	569.321	-85.599	0.837	648.363	-59.251	0.781	1.405	0.3
4	514.149	-55.172	0.540	619.538	-28.825	0.380	1.195	0.3
5	471.220	-42.928	0.420	602.957	-16.581	0.219	1.264	0.3
6[b]	441.418	-29.802	0.292	599.502	-3.455	0.046	1.302	0.3
7	423.173	-18.245	0.178	607.604	8.102	-0.107	1.127	0.3
8[a]	409.229	-13.944	0.136	620.007	12.403	-0.163	1.403	0.3

Note. a. Auto selected eight cluster solution through the AIC.

b. Auto selected six cluster solution through the BIC.

c. Manual selection three cluster solution.

The final cluster solution is shown in Table 20 with the total sample and the three sub clusters. The three clusters were labelled 1) 'commercially-oriented firms', 2) 'mature science-based firms' and 3) 'young technology-based firms'. The order of cluster variables is based on the predictor values, where a higher value indicates a higher importance for characterising the clusters.

Table 20 Cluster comparison of 3-cluster science park tenant firm solution

	Total sample (103)				C1 (29)		C2 (37)		C3 (37)		
Cluster variables	*n*	%	Mean	SD	*n*	%	*n*	%	*n*	%	Predictor
Technology industries	52	50			0	0%	15	41%	37	100%	1
Trade, sales, marketing and construction	20	19			0	0%	20	54%	0	0%	0.66
NPD Funnel			1.95	1.46	0.86	1.22	2.68	1.40	2.08	1.21	0.43
Size on park (employees)											
Less than 10	50	49			19	66%	12	32%	19	51%	
Between 10 - 50	32	31			6	21%	8	22%	18	49%	0.33
Between 50 - 250	13	13			4	14%	9	24%	0	0%	
More than 250	8	8			0	0%	8	22%	0	0%	
Scientific research	23	22			0	0%	15	41%	8	22%	0.23
Duration of stay on park (years)			7.88	10.53	7.76	5.92	11.03	15.88	4.84	3.92	0.10

The clusters can be interpreted as follows.

- Cluster 1 ($n = 29/103$). 'Commercially-oriented firms'. This cluster is not active in technology industries and none of the firms are active in 'trade, sales, marketing and construction activities'. Consequently, this group is relatively less active within the phases of the 'NPD funnel' and none of these firms conduct 'scientific research'. Firms are mainly small-sized. Relatively, this group has remained on science parks for a long period. Subsequent tests reveal that firms in this cluster are significantly more active in 'IT / Telecommunications' (34% for cluster members versus 16% for non-members, $p = 0.041$, Fisher's exact test). In contrast, they are significantly less active in 'Biotechnology / Life Sciences' compared to others (7% versus 35% respectively, $p = 0.002$, Fisher's exact test).
- Cluster 2 ($n = 37/103$). 'Mature science-based firms'. This cluster is largely not active in 'technology industries' and a slight majority are active in 'trade, sales, marketing and construction activities'. This group is highly active within all the phases of the 'NPD funnel' and therefore a number of these tenants also conducts 'scientific research'. With regard to firm size all categories are present. Relatively, this group has been on science parks for the longest period.

- ❖ Cluster 3 (n = 37/103). 'Young technology-based firms'. Firms in this cluster are all active in 'technology industries' and none are active in 'trade, sales, marketing and construction activities'. This group is in terms of the 'NPD funnel' phases moderately active and the majority does not conduct 'scientific research'. Firms are either small or medium-sized. Relatively, this group has stayed on science parks for the shortest period. As a result of their size, 'young technology-based firms' are in comparison to the second group less active in the NPD funnel. This is in line with the reasoning that in general smaller firms are less capable in covering all phases necessary to complete and launch innovations (Brunswicker and Vanhaverbeke, 2015).

4.4.3. Importance science park attributes and perceived benefits

Table 21 shows the conditional probabilities of the benefits for each given specific attribute. Respondents selected the option not applicable (N/A) for attributes that were irrelevant for them. In general, the majority of attributes was associated to one or more benefit(s): only 8% (113) of all attributes had no benefits associated to them.

A chi-square test of goodness of fit showed that the 'not applicable' (N/A) option is not equally distributed across the fifteen attributes. The science park firms in this sample associated attributes and the N/A option significantly different from the expected probabilities, χ^2 (14, n = 1,469) = 44.58, $p < 0.000$. This reveals that the importance of attributes is unequal according to science park firms. Excluding the N/A option, the selection of six out of the seven identified benefits is not equal to the expected equal probabilities χ^2 (6, n = 1,356), $p < 0.000$). Selection of benefits compared to the marginal probability of benefits χ^2 (6, n = 1,356), knowledge $\chi^2 = 113.51$, $p < 0.000$, university $\chi^2 = 26.40$, $p < 0.000$, firms $\chi^2 = 67.86$, $p < 0.000$, customers $\chi^2 = 25.65$, $p < 0.000$, liveability $\chi^2 = 43.50$, $p < 0.000$, image $\chi^2 = 0.24$, $p = 0.99$, cost $\chi^2 = 47.48$, $p < 0.000$. Only the image benefit is not significantly different from random chance, which suggests that this benefit is not associated to any attributes in specific. Respondents chose up to two benefits that they perceive as important for their organisation independent from science park attributes (hereafter principal benefits). Although respondents were allowed to select less than two or even zero principal benefits, only few did not select two options.

Table 21 Association of perceived benefits given science park facilities and services

Attributes	Knowledge	University	Firms	Customers	Liveability	Image	Cost	N/A	*N* (total)	
R&D	22%	13%	6%	5%	2%	7%	33%	11%	98	7%
Equipment	20%	11%	8%	3%	1%	3%	44%	11%	80	5%
Specials	24%	8%	11%	3%	5%	5%	35%	10%	63	4%
Workspace	24%	4%	5%	9%	9%	18%	25%	7%	158	11%
Business support	21%	3%	1%	2%	16%	7%	39%	10%	94	6%
Training	45%	17%	4%	13%	4%	5%	7%	6%	104	7%
Park management	2%	1%	1%	1%	36%	22%	29%	8%	136	9%
Information	45%	21%	4%	8%	2%	3%	9%	8%	91	6%
Venture capital	29%	2%	8%	17%	2%	13%	6%	23%	48	3%
Networking	35%	14%	10%	20%	4%	9%	5%	2%	171	12%
Social	23%	7%	9%	12%	26%	16%	2%	5%	132	9%
Dining	9%	2%	2%	5%	41%	12%	18%	11%	132	9%
Residential	15%	4%			37%	15%	26%	4%	27	2%
Leisure	4%	1%		1%	59%	22%	7%	4%	69	5%
Additional	5%	2%		2%	56%	21%	11%	5%	66	4%
B_j mean	22%	8%	5%	8%	19%	12%	19%	8%	100%	100%
	328	114	72	115	273	177	277	113	1,469	

Table 22 shows the principal benefits ordered on frequency in the first column and the rank order based on associations with attributes in the last column. The latter rank order is based on the total number of times each benefit is mentioned in the context of an attribute (the last row in Table 22). 'Knowledge sharing and collaboration' and 'proximity of university' were most frequently chosen. Followed by 'proximity of firms in similar sectors', 'image and prestige of the site', 'proximity of markets and customers' and 'cost of accommodation and services'. The least chosen benefits were 'liveability of the site' and 'others'. Open answers given by respondents for 'others' were: shared marketing, expansion possibilities, access to professional networks, search for investors and specific R&D facilities. It is noted that some of these answers given by the respondents are not strictly benefits, but are more similar to attributes. This is not considered a major issue as the benefit 'others' is selected only seven times across all respondents. Among all choices made, none of the principal benefits was chosen by the majority of the respondents, which shows the diversity of perceptions within the total group.

Table 22 Frequency of principal benefits and rank order based on association with attributes

Benefit (*n* = 187)	%	Rank in association
Knowledge sharing and collaboration	21%	1
Proximity of university	20%	6
Proximity of firms in similar sectors	14%	7
Image and prestige of the site	14%	4
Proximity of markets and customers	11%	5
Cost of accommodation and services	11%	2
Liveability of the site	4%	3
Others	4%	-

'Knowledge sharing and collaboration' was most frequently chosen as principle benefit and much less frequently in the context of attributes regarding facilities and services. In addition, both 'university' and 'firms' were frequently chosen principal benefits, but these two benefits were also far less often associated with such attributes (respectively, the sixth and seventh rank). In contrast, 'liveability' and 'cost' were associated with attributes more frequently, but were less chosen as principal benefits of a science park. The associations between the attributes and perceived benefits will be discussed more in-depth in the next section.

4.4.4. Associations between attributes and benefits

This study aims to reveal the link between science park attributes and perceived benefits. Therefore, the instances of 'not applicable' were not considered for the analysis of associations between attributes and benefits. This brings the sample on the level of associations to 1,356 attribute-benefit pairs judged by the respondents.

Table 23 Observed, expected and chi-square values on facility and service level

Attributes	Knowledge	University	Firms	Customers	Liveability	Image	Cost	χ^2
R&D-Ob.	22	13	6	5	2	7	32	χ^2 (6, n = 87)
R&D-Ex.	21	7	5	7	18	11	18	
R&D-χ^2	0.04	4.42	0.41	0.77	13.74	1.67	11.39	32.45, $p < 0.000$
Equipment-Ob.	16	9	6	2	1	2	35	χ^2 (6, n = 71)
Equipment-Ex.	17	6	4	6	14	9	15	
Equipment-χ^2	0.08	1.54	1.32	2.69	12.36	5.70	28.96	52.65, $p < 0.000$
Specials-Ob.	15	5	7	2	3	3	22	
Specials-Ex.	14	5	3	5	11	7	12	χ^2 (6, n = 57) 25.11, $p < 0.000$
Specials-χ^2	0.11	0.01	5.22	1.66	6.26	2.65	9.21	
Workspace-Ob.	38	6	8	14	14	28	39	χ^2 (6, n = 147)
Workspace-Ex.	36	12	8	12	30	19	30	
Workspace-χ^2	0.17	3.27	0.00	0.19	8.22	4.05	2.68	18.58, $p < 0.005$
Business support-Ob.	20	3	1	2	15	7	37	χ^2 (6, n = 85)
Business support-Ex.	21	7	5	7	17	11	17	
Business support-χ^2	0.02	2.41	2.73	3.76	0.26	1.51	22.21	32.90, $p < 0.000$
Training-Ob.	47	18	4	13	4	5	7	χ^2 (6, n = 98)
Training-Ex.	24	8	5	8	20	13	20	
Training-χ^2	22.89	11.56	0.28	2.65	12.54	4.75	8.47	63.13, $p < 0.000$
Park management-Ob.	3	1	1	2	49	30	39	χ^2 (6, n = 125)
Park management-Ex.	30	11	7	11	25	16	26	
Park management-χ^2	24.53	8.60	4.79	6.98	22.57	11.48	7.10	86.05, $p < 0.000$
Information-Ob.	41	19	4	7	2	3	8	χ^2 (6, n = 84)
Information-Ex.	20	7	4	7	17	11	17	
Information-χ^2	21.05	20.18	0.05	0.00	13.15	5.79	4.89	65.10, $p < 0.000$

A chi-square test for each of the fifteen attributes was done to determine if the observed counts between a specific attribute and benefit differs significantly from the expected probabilities. The expected probability of an A_i-B_j association is the product of the $P(B_j)$ and the number of associations of A_i (Table 23). Relatively less often a benefit was selected for 'venture capital' and 'residential' attributes, which led to small observed and expected counts meaning that the chi-square test was not applicable. Chi-square tests on the remaining thirteen attributes are all highly significant ($p < 0.005$) and these associations are further discussed.

Table 23 (continued)

Attributes	Knowledge	University	Firms	Customers	Liveability	Image	Cost	χ^2
Venture capital-Ob.	14	1	4	8	1	6	3	*More than 20% of expected values < 5.*
Venture capital-Ex.	9	3	2	3	7	5	8	
Venture capital-χ^2								
Networking-Ob.	60	24	17	35	6	16	9	χ^2 (6, n = 167)
Networking-Ex.	40	14	9	14	34	22	34	
Networking-χ^2	9.51	7.07	7.46	30.66	22.69	1.54	18.49	97.42, $p < 0.000$
Social-Ob.	30	9	12	16	34	21	3	χ^2 (6, n = 125)
Social-Ex.	30	11	7	11	25	16	26	
Social-χ^2	0.00	0.22	4.33	2.75	3.10	1.34	19.89	31.63, $p < 0.000$
Dining-Ob.	12	3	2	7	54	16	24	χ^2 (6, n = 118)
Dining-Ex.	29	10	6	10	24	15	24	
Dining-χ^2	9.59	4.83	2.90	0.90	38.50	0.02	0.00	56.75, $p < 0.000$
Residential-Ob.	4	1	0	0	10	4	7	*More than 20% of expected values < 5.*
Residential-Ex.	6	2	1	2	5	3	5	
Residential-χ^2								
Leisure-Ob.	3	1	0	1	41	15	5	χ^2 (6, n = 66)
Leisure-Ex.	16	6	4	6	13	9	13	
Leisure-χ^2	10.53	3.73	3.50	3.78	57.80	4.73	5.34	89.40, $p < 0.000$
Additional-Ob.	3	1	0	1	37	14	7	χ^2 (6, n = 63)
Additional-Ex.	15	5	3	5	13	8	13	
Additional-χ^2	9.83	3.49	3.35	3.53	46.62	4.06	2.68	73.54, $p < 0.000$
Totals	328	114	72	115	273	177	277	1,356 (n)
	24%	8%	5%	8%	20%	13%	20%	100%

The lift ratio (I), where the conditional probability of a benefit given an attribute is divided by the overall probability of that benefit, was used to investigate the association strength between attributes and benefits. A lift ratio higher than one indicates an association between an attribute and a benefit. While a value of one or lower indicates that the benefit is not associated to the attribute. Table 24 lists the lift ratios of all attribute–benefit pairs. Two thresholds are chosen for emphasising interesting associations; for strong associations (> 1.5) and for pairs that are not associated (< 0.5).

Table 24 Lift ratios facilities/services and benefits

Attributes	Knowledge	University	Firms	Customers	Liveability	Image	Cost
R&D	1.05	1.78	1.30	0.68	0.11	0.62	1.80
Equipment	0.93	1.51	1.59	0.33	0.07	0.22	2.41
Specials	1.09	1.04	2.31	0.41	0.26	0.40	1.89
Workspace	1.07	0.49	1.02	1.12	0.47	1.46	1.30
Business support	0.97	0.42	0.22	0.28	0.88	0.63	2.13
Training	1.98	2.18	0.77	1.56	0.20	0.39	0.35
Park management	0.10	0.10	0.15	0.19	1.95	1.84	1.53
Information	2.02	2.69	0.90	0.98	0.12	0.27	0.47
Networking	1.49	1.71	1.92	2.47	0.18	0.73	0.26
Social	0.99	0.86	1.81	1.51	1.35	1.29	0.12
Dining	0.42	0.30	0.32	0.70	2.27	1.04	1.00
Leisure	0.19	0.18		0.18	3.09	1.74	0.37
Additional	0.20	0.19		0.19	2.92	1.70	0.54

Note. Dark grey strong associations ($I > 1.5$), light grey not associated ($I < 0.5$).

Next, for each benefit, the most interesting associations are discussed.

Firstly, the knowledge benefit, which stands for knowledge sharing and collaborative opportunities, is most strongly associated with information access and training programs and, as expected, least associated for the more supporting facilities that a science park could offer. This benefit is also associated with business networking events, but is not associated with social events. Moreover, science park facilities (i.e., R&D, specials and workspace) are not associated with knowledge benefits. This suggests that the use of these facilities is not perceived to lead to mutual learning among different organisations. Secondly, proximity of university is associated with both research-related facilities and content-related services. The former might suggest that the usage of these facilities allows tenants to be near academic staff. However, social events are not associated with university as science park firms are more interested on acquiring academic insights through information, training and networking events. The proximity of firms benefit is associated through the majority of the research-related facilities suggesting that there is some form of co-presence with other organisations at science parks.

Furthermore, respondents associated the proximity of markets and customers benefit to the attributes business networking events, training programs and social events. On the other hand, it seems that within this sample dining facilities are not used abundantly for inviting clients to the science park. Similar to proximity of firms, both social events and networking events are beneficial to get near to clients (customers).

The liveability benefit, which is related to spatial quality, is most strongly associated with leisure, additional (i.e., bike repair shop, day care etc.), dining and park management. In contrast, the research and work-related facilities are not associated with liveability. Moreover, events within the context of business networking, such as conferences or seminars are not associated with liveability. While social events are somewhat associated with this benefit. The image associations are to some extent similar to liveability. Respondents perceived image benefits to be related to park management, leisure and additional facilities. The research-related facilities are also not associated with image benefits. One exception is the association made with workspace, which could be related to the high-quality buildings commonly present on science parks.

Lastly, cost benefits are mainly associated with research and work-related facilities, business support and park management. These attributes are likely to be selected as a result of economies of scale derived from shared facilities and services. A large number of services are not associated with cost benefits. The attributes training, information, networking, social and leisure do not lead to some form of cost saving. These services are likely to be perceived as costly compared to their added value.

4.4.5. *Tenant types and associations between attributes and benefits*

Each cluster of tenant firms was compared with the total group. Table 25 shows for each cluster the frequencies with which benefits are associated to attributes across all attributes.

Table 25 Associated benefits among tenant types and total group

Cluster	Knowledge	University	Firms	Customers	Liveability	Image	Cost	Total
Commercial	18%	7%	6%	14%	22%	15%	18%	384
Mature science	28%	9%	3%	6%	18%	13%	22%	475
Young technology	25%	9%	7%	6%	21%	11%	21%	497
Total group	24%	8%	5%	8%	20%	13%	20%	100%
	328	114	72	115	273	177	277	1,356

A chi-square test was performed to determine if the (seven) benefits were selected with equal probabilities between the clusters. It turns out that commercially-oriented firms, mature science-based firms and young technology-based firms associate benefits significantly different from each other, $\chi^2(12, n = 1{,}356) = 44.30$, $p < 0.000$. Commercially-oriented firms associate attributes most often with liveability benefits followed by knowledge and cost. However, the frequency of these latter two benefits are somewhat lower compared to the other two clusters.

Furthermore, commercially-oriented firms associate customers with attributes more frequently than the group average. Mature science-based firms associate knowledge and cost more than the group average, while this cluster selects firms less often than the other clusters. Young technology-based firms associate knowledge and cost benefits in similar fashion as mature science-based firms, although more attributes are associated with firms.

For each of the three clusters, the lift ratios (*I*) are discussed in which the conditional probability of a specific benefit given a specific attribute was compared with the unconditional probability of that benefit. The conditional probabilities and lift ratios of all A-B associations broken down to commercially-oriented firms, mature science-based firms and young technology-based firms are found in Tables 26, 27 and 28.

Table 26 Commercially-oriented firms - conditional probabilities and lift ratios (I)

Attributes	Knowledge		University		Firms		Customers		Liveability		Image		Cost		n	A_i mean
R&D	14%	0.77	29%	4.39	7%	1.19	7%	0.51			7%	0.48	36%	1.96	14	4%
Equipment	15%	0.83	15%	2.36	15%	2.57	8%	0.55					46%	2.53	13	3%
Specials	13%	0.68			25%	4.17	13%	0.89			13%	0.84	38%	2.06	8	2%
Workspace	28%	1.51			5%	0.78	23%	1.65	7%	0.32	19%	1.25	19%	1.02	43	11%
Business support	10%	0.52	3%	0.50			3%	0.23	29%	1.33	6%	0.43	48%	2.65	31	8%
Training	32%	1.74	16%	2.48	10%	1.62	16%	1.15	10%	0.44	6%	0.43	10%	0.53	31	8%
Park management	3%	0.14					5%	0.37	39%	1.80	21%	1.42	32%	1.73	38	10%
Information	48%	2.60	20%	3.07	4%	0.67	12%	0.85	4%	0.18	4%	0.27	8%	0.44	25	7%
Venture capital															10	3%
Networking	26%	1.41	10%	1.54	12%	2.00	30%	2.13	6%	0.27	12%	0.81	4%	0.22	50	13%
Social	26%	1.39	3%	0.39	10%	1.71	18%	1.28	26%	1.17	15%	1.04	3%	0.14	39	10%
Dining	5%	0.29	3%	0.42			8%	0.58	41%	1.85	22%	1.46	22%	1.19	37	10%
Residential															5	1%
Leisure	5%	0.25	5%	0.70			5%	0.32	59%	2.70	23%	1.53	5%	0.25	22	6%
Additional									56%	2.54	33%	2.25	11%	0.61	18	5%
B_j mean	18%		7%		6%		14%		22%		15%		18%		100%	100%
	71		25		23		54		84		57		70		384	

Note. Dark grey strong associations ($I > 1.5$), light grey not associated ($I < 0.5$).

Table 27 Mature science-based firms - conditional probabilities and lift ratios (*I*)

Attributes	Knowledge		University		Firms		Customers		Liveability		Image		Cost		*n*	A_i mean
R&D	28%	0.98	17%	1.80	3%	0.94	8%	1.32			8%	0.62	36%	1.67	36	8%
Equipment	30%	1.07	13%	1.41									57%	2.61	23	5%
Specials	29%	1.03	13%	1.35	8%	2.83					4%	0.31	46%	2.11	24	5%
Workspace	25%	0.86	6%	0.61	4%	1.28	2%	0.30	11%	0.63	23%	1.68	30%	1.39	53	11%
Business support	32%	1.13							4%	0.22	16%	1.19	48%	2.21	25	5%
Training	58%	2.03	18%	1.96			15%	2.40			6%	0.45	3%	0.14	33	7%
Park management	2%	0.08							39%	2.16	32%	2.36	27%	1.26	44	9%
Information	62%	2.17	23%	2.49			8%	1.22			4%	0.29	4%	0.18	26	5%
Venture capital															10	2%
Networking	39%	1.38	16%	1.77	8%	2.78	15%	2.34	3%	0.18	11%	0.85	7%	0.30	61	13%
Social	23%	0.82	9%	0.92	9%	2.89	13%	2.02	28%	1.55	17%	1.26	2%	0.10	47	10%
Dining	18%	0.65	3%	0.28			5%	0.83	45%	2.50	5%	0.39	24%	1.09	38	8%
Residential															9	2%
Leisure	8%	0.28							56%	3.13	24%	1.78	12%	0.55	25	5%
Additional	14%	0.50							62%	3.46	10%	0.71	14%	0.66	21	4%
B_j mean	28%		9%		3%		6%		18%		13%		22%		100%	100%
	135		44		14		30		85		64		103		475	

Note. Dark grey strong associations ($I > 1.5$), light grey not associated ($I < 0.5$).

Table 28 Young technology-based firms - conditional probabilities and lift ratios (*I*)

Attributes	Knowledge		University		Firms		Customers		Liveability		Image		Cost		*n*	A_i mean
R&D	27%	1.10	8%	0.90	11%	1.54	3%	0.43	5%	0.26	8%	0.72	38%	1.81	37	7%
Equipment	20%	0.81	11%	1.26	11%	1.62	3%	0.46	3%	0.14	6%	0.51	46%	2.18	35	7%
Specials	28%	1.14	8%	0.88	12%	1.70	4%	0.64	12%	0.57	4%	0.36	32%	1.53	25	5%
Workspace	25%	1.04	6%	0.65	8%	1.11	6%	0.94	10%	0.47	16%	1.39	29%	1.41	51	10%
Business support	31%	1.26	7%	0.76	3%	0.49	3%	0.55	17%	0.82	3%	0.31	34%	1.65	29	6%
Training	53%	2.16	21%	2.27	3%	0.42	9%	1.41	3%	0.14	3%	0.26	9%	0.42	34	7%
Park management	2%	0.09	2%	0.26	2%	0.33			40%	1.89	19%	1.65	35%	1.67	43	9%
Information	39%	1.60	24%	2.68	9%	1.29	6%	0.97	3%	0.14	3%	0.27	15%	0.72	33	7%
Venture capital															17	3%
Networking	41%	1.67	16%	1.78	11%	1.52	20%	3.15	2%	0.09	5%	0.48	5%	0.26	56	11%
Social	23%	0.94	10%	1.13	10%	1.46	8%	1.23	28%	1.35	18%	1.59	3%	0.12	39	8%
Dining	7%	0.28	2%	0.26	5%	0.66	5%	0.75	51%	2.44	14%	1.24	16%	0.78	43	9%
Residential															12	2%
Leisure									74%	3.52	21%	1.87	5%	0.25	19	4%
Additional			4%	0.46			4%	0.67	58%	2.79	25%	2.22	8%	0.40	24	5%
B_j mean	25%		9%		7%		6%		21%		11%		21%		100%	100%
	122		45		35		31		104		56		104		497	

Note. Dark grey strong associations ($I > 1.5$), light grey not associated ($I < 0.5$).

Between the three tenant types no differences are found among the highest lift ratios for specials, business support, information, dining, leisure and additional attributes. In Table 29, for each attribute, the most associated benefits are listed per cluster based on the lift ratio. The shaded cells within the table indicate benefits that are associated by clusters that differ from the total group. Only nine attribute-benefit pairs are different from the total group, which suggests that the perceived benefits for attributes are quite consistent compared to the overall group.

Table 29 Most associated benefits with facilities and services per science park tenant type

	Commercial		Mature science		Young technology	
R&D	University	4.39	University	1.80	Cost	1.81
Equipment	Firms	2.57	Cost	2.61	Cost	2.18
Specials	Firms	4.17	Firms	2.83	Firms	1.70
Workspace	Customers	1.65	Image	1.68	Cost	1.41
Business support	Cost	2.65	Cost	2.21	Cost	1.65
Training	University	2.48	Customers	2.40	University	2.27
Park management	Liveability	1.80	Image	2.36	Liveability	1.89
Information	University	3.07	University	2.49	University	2.68
Networking	Customers	2.13	Firms	2.78	Customers	3.15
Social	Firms	1.71	Firms	2.89	Image	1.59
Dining	Liveability	1.85	Liveability	2.50	Liveability	2.44
Leisure	Liveability	2.70	Liveability	3.13	Liveability	3.52
Additional	Liveability	2.54	Liveability	3.46	Liveability	2.79

Note. Shaded cells indicate most associated benefits that are different from the total group.

Compared to the total group there are some differences among the clusters in the sample. Workspace is the only attribute that is associated by each tenant type to a different benefit. An explanation is that the total group did not associate workspace with a specific benefit strongly, which results in these different perceptions. For R&D the first two clusters associate this attribute the most strongly with university. It is important to note that the research-related attributes (i.e., R&D, equipment and specials) are selected less often by commercially-oriented firms than the other two clusters. In contrast, one of the main benefits for this group is proximity of markets and customers as this is related to workspace and networking events, which are the most frequently chosen attributes (respectively 11% and 13% across all associations). For workspace, commercially-oriented firms are significantly more likely to select the customers benefit than firms of other clusters (23% versus 4% respectively, $p < 0.001$, Fisher's exact test). For mature science-based firms the perceived benefit for training programs is to be near customers, while the other two clusters relate this attribute predominantly to university benefits. Furthermore, while park management is generally perceived to be contributing to the liveability of the science park, this cluster associates this service more towards image benefits.

Likewise, mature science-based firms associate business networking events relatively more often to be near other firms than the other two clusters. Lastly, young technology-based firms differ from the others on cost benefits through workspaces and image benefits through social events.

4.5. Discussion

The results show that tenant firms on science parks in the Netherlands perceive different benefits from the different facilities and services attributes that science parks offer. Overall, both training programs and business networking events are associated by science park firms to proximity benefits (i.e., nearness to certain actors), while park management, leisure and additional facilities are more strongly related to liveability and image benefits (park management is also associated with cost saving). Important to note is that in the perception of tenants each attribute serves a specific purpose. Research-related facilities are an exception (i.e., R&D, equipment and specials) as these attributes are associated to both proximity benefits and cost benefits.

This study expands past research on perceived benefits through the analysis of the conditional probabilities of these benefits given science park attributes and by considering the diversity among tenant types. Looking at the principal benefits, the most important ones are 'knowledge sharing and collaboration' and 'proximity of university' benefits, which is in line with previous work by Ferguson and Olofsson (2004) and Dettwiler et al. (2006), although in this study, the a priori selection of these two benefits was not heavily favoured over the other five benefits. Similar to the study of Van Dierdonck et al. (1991), the university was not the most important location aspect of science parks among all science park tenant firms and financial motives and the accessibility of the science park were also influential in their decision-making. This reveals that science park tenants are looking for a broad range of benefits a science park can offer. The option for own input besides predefined benefits from literature was given, but not used frequently by respondents.

First, the main contribution of this study to the science park literature is linking specific types of science park facilities and services to the possible benefits tenants perceive. Only a limited amount of research has been conducted on the tenants' needs of science park facilities and services (Albahari et al., 2019). Several patterns emerge from the analysis. 'Proximity of university' benefits are attained through the attributes R&D, equipment, training programs, information access and business networking events. Possibly, science park firms interpret these attributes as potential ways for fostering relations with the university. In contrast, only training programs and information access attributes are associated with knowledge benefits. This suggests that science parks should look beyond the primary facilities and services for enabling knowledge benefits between park tenants. When cognitive barriers are considered, Chen et al. (2016) posited that business partners within the same value chain are essential for improved innovation performance, which suggests that preferences for specific partner types exist. In this study, science park firms associate proximity of similar firms to research-related facilities and social and business networking events. The former suggests that the shared usage of research-related facilities between firms is not only seen as a way for cost saving, but can also contribute to proximity benefits.

The selection of 'image and prestige of the site' was not significantly different compared to the expected distribution of equal chance among benefits. This suggests that image benefits are achieved through the total package of attributes and not just from the way the science park looks.

Second, within this study it is also considered that science parks may accommodate a heterogeneous group of firms. Past research has argued the importance of acknowledging the heterogeneous composition of science park firms (Ferguson and Olofsson, 2004; Chan and Lau, 2005; Díez-Vial and Fernández-Olmos, 2015; Ubeda et al., 2019). The cluster analyses show three different science park tenant types based on (dis)similarities on activities, size and length of stay. The average duration of stay of 4.84 years for the cluster located the shortest on a science park, should already provide for a sufficient period for these tenants to actually experience benefits from the science park attributes (Liberati et al., 2016).

The first tenant type, commercially-oriented firms associate attributes more often with proximity of markets and customers than the other two tenant types, which is in line with their weaker focus on research-based activities. This group mainly perceives workspaces and networking events as ways to be near their customers. These attributes could ultimately allow tenants to venture in new markets and are especially beneficial for new product development (Van Der Borgh et al., 2012).

The second tenant type, mature science-based firms associate networking events with the proximity of firms more often. Moderately-sized firms are likely to depend on networks due to the absence of market knowledge and new technology or in order to improve their own products (Van De Vrande et al., 2009). Compared to younger firms within the sample, mature firms expected knowledge sharing and collaboration to happen relatively less through training programs. The knowledge of mature firms is more likely to be more explicit than tacit and therefore more exposed to competition (McAdams and McAdams, 2008; Díez-Vial and Fernández-Olmos, 2017). Stronger associations are found between R&D, training and networking attributes and the proximity benefits: university, customers and firms. Díez-Vial and Fernandéz-Olmos (2015) argued that firms with more prior experience in collaborating with universities are more likely to benefit from their stay on science parks. The mature science-based firms within the sample have stayed relatively the longest on their science parks, which might explain their positive perception towards the university. However, the effectiveness of knowledge for tenant firms with high absorptive capacity might reduce as a result of knowledge duplicity (Ubeda et al., 2019). Furthermore, Gassmann et al. (2010) suggested that larger firms are motivated to engage in open innovation strategies as a means to be near their markets and to access potential human talent in order to expand their knowledge base. This is further underlined in this study where it is found that mature science-based firms associate training programs (developing human talent) with proximity of customers (improving offering to customer needs) more often than the other two tenant types.

The last tenant type, young technology-based firms, which are smaller and younger, value cost benefits more through their workspaces and image benefits more through social events. These findings are in line with Ferguson and Olofsson (2004) and Clarysse and Bruneel (2007) that besides money, start-ups also seek support in interacting with others and legitimacy.

For small-medium enterprises a liability to adopt open innovation strategies is their small size, which restricts their management of these processes and may result in less benefits (Gassmann et al., 2010). This could explain why this group is relatively more cost-driven and this would underscore the provision of shared facilities and services on science parks aimed at smaller and younger firms. However, from an R&D management perspective, Oakey (2007) suggested that some reluctance to collaborate among start-ups on science parks is present, because of confidentiality and competing in similar local markets. In contrast, from a commercial perspective, Heydebreck et al. (2000) suggested that technology-based start-ups are required to seek out global opportunities to launch their innovations in order to break-even from their R&D expenses, which could partly explain why firms consider business networking events primarily as a way to be near customers. Moreover, the socialisation process among organisations on science parks is beneficial for knowledge sharing as emphasised in Inomata (2016). Compared to the other firm types, young technology-based firms associate cost benefits considerably less often with business support. This could indicate that this group perceives the expenses of these services as a disadvantage, given limited financial resources available (Westhead and Batstone, 1999; Chan and Lau, 2005).

4.6. Conclusion and limitations

This study focused on the benefits that science park tenants perceive from science park attributes related to the facilities and services on park. In order to gain insight in the added value of science park attributes, park tenant representatives were asked how they associate proximity and science park related benefits to the offered science park facilities and services. In a cluster analysis three different tenant types are found based on organisational characteristics. The attribute-benefit associations made by these tenant types were further analysed as science parks cater to a wide range of tenants (Lecluyse et al., 2019). This study contributes to both theory and science park practice. From an academic perspective this study offers additional insights in the further conceptualisation of science park development from the perspective of tenants, which was identified by Mora-Valentín et al. (2019) as a research gap. This study sheds light on what role science park facilities and services play for significantly different tenant types to attain various perceived benefits. Within the Dutch context, science parks are home to a vast range of technology and science-based firms, but also more commercially-oriented counterparts who are more focused on valorising knowledge. Considering these different tenant types, different benefits are associated through different science park attributes. For practitioners, this study reveals that there are different needs among tenant types, which are related to perceived benefits that are obtained through specific science park attributes. These needs are studied through the user-side (i.e., the facilities and services) of what a science park offers. Science park developers and managers should consider which type of firms they want to target and configure their facilities and services accordingly in order to meet the demands of their target group(s).

The more commercially-oriented firms focus more on being near to their clients. For the other more technology and science-based counterparts image benefits are important. The more mature firms seek ways to be near the university, customers and similar firms, while younger firms are more cost-driven. In this study several (principal) benefits, such as proximity of university and proximity of firms, are perceived as important. However, when related to science park attributes these important principal benefits are selected less frequently. This shows that in the perception of park tenants, while science parks could provide these benefits for them, the facilities or services are limited in aiding firms in achieving these organisational goals. Moreover, this study reveals that the added value of science park attributes extends further than simple location-based support (i.e., park management, business support), as training programs and networking services that a science park offers are also perceived as a way to gain knowledge and to be near the university, customers and other firms. A science park providing ‘information access’, ‘business networking events’ and ‘training programs’ could aid firms in improving their product and service offerings. This implies that policy attention should be given to the design and management of science parks that extend beyond being mere property initiatives, into places that facilitate proximity and potentially innovation.

This study is not without limitations. Firstly, as the sample included only Dutch firms it only gives a limited view on the perception of park tenants in the Netherlands. For this country the results are still difficult to generalise as it only included firms from seven of seventeen eligible science parks and the sample distribution is not representative among these seven science parks. So future research on perceived benefits in relation to science park attributes should be conducted in other countries as well with a more random sample, in order to look for national differences. A second limitation is that this research approach is based on data collection on one moment in time. Díez-Vial and Fernández-Olmos (2017) posited that the value that science parks offer to firms is dynamic in time due to contextual and structural factors. This suggests that more longitudinal work should be done as the perceived benefits of science park attributes are likely to be dynamic. Thirdly, the a priori list of attributes and benefits that was presented to respondents is derived from literature and in order to reduce respondent burden the total number was kept limited. Moreover, the scope of the study is confined to the science park facilities and services, while factors related to location, such as accessibility by public transport or car were not considered. Therefore, it is interesting in future studies to use more open formats that allow to measure attribute-benefit associations based on recall instead of recognition. Finally, the present study only focused on attribute-benefit associations. To measure link strengths as well as weights assigned to benefits, a more rigorous econometric framework as developed in Arentze et al. (2015) and Dellaert et al. (2017) can be considered to contribute to a further understanding of the science park concept.

CHAPTER FIVE

Perceptual Measures of Science Parks

This chapter is based on:

Ng, W. K. B., Appel - Meulenbroek, H. A. J. A., Cloodt, M. M. A. H., Arentze, T. A. (Submitted). Perceptual Measures of Science Parks: Tenant Firms' Associations between Science Park Attributes and Benefits.

5.1. Introduction

Science parks are managed area developments that provide accommodation for knowledge-based firms and institutions to conduct knowledge-intensive activities (e.g., Westhead and Batstone, 1999; Albahari et al., 2016). Within the innovation policy research, science parks are considered as more traditional supply-side innovation policy measures, aimed at contributing to networking among co-located actors and subsequent innovative and economic activities (Edler and Georghiou, 2007). Science parks appear in many forms, providing a large range of facilities and services to higher educational institutions, research institutes and firms from various business development phases (Ng et al., 2019a). Moreover, it is argued that science parks enhance the performance of firms and ultimately contribute to more competitive regions (Bigliardi et al., 2006). Since the 1990s there has been considerable academic attention given to proving the impact that science parks have on firms, which was often studied through comparing on- and off-park firms. However, univocal evidence has not been found for their positive impact on performance of on-park firms (Albahari et al., 2010; Lecluyse et al., 2019). Some authors addressed the need for additional research on perceptual measures such as perceived benefits or values of science park firms (Albahari et al., 2018; Lecluyse et al., 2019). The lack of evidence regarding positive science park impact could be caused by disregarding the proper measures to assess this impact. Therefore, perceptual measures might also explain a part of the science park impact not captured by the traditional performance indicators. The study on tenant firms' perceptual measures of science parks include important location motivation decisions (Van Dierdonck et al., 1991), perceived benefits of the management function on science parks (Westhead and Batstone, 1999) and the perceived benefits of the science park location (Dettwiler et al., 2006). Other perceptual science park studies include the relation between growth rates of start-ups and perceived location benefits (Ferguson and Olofsson, 2004), perceived value of science park facilities and services among Swedish science park cases (Albahari et al., 2019) and the link between different types of science park facilities and services and different types of perceived benefits (Ng et al., 2019b). These studies are characterised by their focus on a limited number of attributes (i.e., science park location or other science park aspects) and the link between these science park attributes and perceptual measures.

Compared to performance measures, perceptual measures are suggested to be more able to account for the different objectives among different firms (Lecluyse et al., 2019). Moreover, additional research on perceptual measures can complement evaluation research by revealing which types of performance indicators are important from the perspective of the tenant firms and could be considered in future science park evaluations. It provides for more detailed input for how science park managers can make area developments designated for knowledge-based firms more effective and future-proof. As science parks are often realised through financial support of public bodies, well-functioning science parks are desirable for society (Monck and Peters, 2009).

To address the demand-side, this study will explore attribute-benefit links on relevant attributes that science park management can provide to attain specific benefits for tenant firms. A means-end approach, originating from marketing literature, is used to investigate the links. This theory proposes that individuals acquire products not for the product itself, but for what the product can do for them (Ter Hofstede et al., 1998). There is little prior empiric research exploring the relationship between attributes and perceived benefits this way. Previous work of Ng et al. (2019b) explored the link between science park attributes on facility and service level and perceived benefits related to these facilities and services. Moreover, they distinguished different tenant types through organisational characteristics with each type having different associations. The authors showed that tenant firms on science parks are a heterogeneous group with different needs. In comparison to that study this current work focuses on a much larger range of science park attributes beyond facilities and services and includes more benefits derived from existing science park evaluation research, in order to provide an overall view of what a science park could mean for a tenant. Due to the broad scope, this is an exploratory study without the intention to generalise the findings with regard to firm characteristics or firm types.

Specifically, the research question is: "*Which perceived benefits are important according to science park firms and which science park attributes are associated to attaining these perceived benefits?*" This study on the perceived added value of science park attributes contributes to both academia and practice. The theoretical contribution leads to a further understanding of the science park concept and knowledge-based area development in general with a focus on the needs of tenants (Mora-Valentín et al., 2018). A negligence of tenant needs might affect their performance as a result of inadequate attributes that affect their core business activities. Furthermore, this study contributes to theory as to which attributes are useful to attain which benefits from the perception of tenant firms. In addition, the inclusion of perceived benefits derived from existing science park evaluation research allows for the exploration of benefits that tenants might want to achieve and their importance. This could lead to recommendations of new research directions for future science park evaluation research. Moreover, for urban planners and science park management, the user-focused approach supports more effective science park planning and management and science park configurations that align with current tenants' needs.

In preparation of the empirical data gathering, science park attributes and perceived benefits are derived from previous empiric science park literature (e.g., Ferguson and Olofsson, 2004; Albahari et al., 2016). In the next sections the science park concept is categorised in proximity, real estate and managerial attributes in order to show how science parks can be configured (section 5.2.1, 5.2.2 and 5.2.3). Moreover, in section 5.2.4, prior science park evaluation research is reviewed to highlight potential benefits tenant firms might perceive. Next, the approach and the empirical results are discussed in section 5.3 and 5.4 respectively. In section 5.5, the results are reflected upon and last in section 5.6 the main conclusions, limitations and future research are addressed.

5.2. Literature review – perceived benefits of science park attributes

In this section the various science park attributes and perceived benefits from the perspective of the tenant firms are discussed. Science parks are managed physical area developments focused on stimulating networking and innovative and economic output for its park firms and subsequent region. The following categorisation is chosen for listing the relevant science park attributes: proximity, real estate and managerial attributes. Each science park attribute in these three categories is expected to lead towards potential benefits for the tenant firms based on previous studies, as listed in Table 30, 31 and 32 and discussed below.

5.2.1. Proximity attributes

The high physical proximity between knowledge-intensive actors contributes to socialisation, economies of scale, sharing information, mutual learning and increased innovative output (Jaffe, 1989; Rosenkopf and Almeida, 2003; Storper and Venables, 2004). The proximity attributes consist of the geographical proximity to various actors: university, research institute, similar firms, well-known firms, competitors, new customers and existing customers (Table 30).

Table 30 Proximity attributes

<table>
<tr><th>Attribute description</th><th>Source</th></tr>
<tr><td>Geographical proximity to university is high.</td><td>Ferguson and Olofsson, 2004; Dettwiler et al., 2006; Link and Scott, 2006; Fukugawa, 2013</td></tr>
<tr><td>Geographical proximity to research institutes is high.</td><td>Fukugawa, 2006; Link and Scott, 2006</td></tr>
<tr><td>Geographical proximity to similar firms is high.</td><td rowspan="4">Lindelöf and Löfsten, 2003; Dettwiler et al., 2006</td></tr>
<tr><td>Geographical proximity to well-known firms is high.</td></tr>
<tr><td>Geographical proximity to competitors is high.</td></tr>
<tr><td>Geographical proximity to existing customers is high.</td></tr>
<tr><td>Geographical proximity to new customers is high.</td><td>Ferguson and Olofsson, 2004</td></tr>
</table>

Several of these proximity attributes were surveyed among 273 new technology-based firms in Sweden by Lindelöf and Lofsten (2003) and this sample was further analysed by the same authors in 2006 (Detwiler et al.). With regard to reasons to locate on a science park, new technology-based firms selected 'nearness to university' as most important, followed by 'nearness to customers', 'to well-known firms', 'to similar firms/partners' and lastly 'to competitors'. The university is seen as a source of human talent, where firms are able to recruit recent graduates (McAdam and McAdam, 2008). Moreover, the proximity to universities and to research institutes has been argued to be related to employee growth on science parks. Employee growth decreases when science parks are located further away from universities because potential means of technology transfer or (unintended) knowledge transfer will be limited (Link and Scott, 2006). New technology-based firms on science parks are more likely to engage in joint research projects with research institutes (Fukugawa, 2006). However, Fukugawa (2013) later also found that being located close to a university is not enough to establish knowledge spillovers channels with new technology-based firms, as the experiences of incubator managers are also vital for technology transfer. In addition, Ferguson and Olofsson (2004) did not find significant growth differences between on- or off-park firms in reporting higher benefits among new technology-based firms that selected 'access to new customers' as an important motivation to locate on a science park. But in general, the co-presence of various actors and the resulting socialising enhance ties between those actors and facilitate knowledge sharing (Inomata et al., 2016). Besides higher educational institutions, established firms active in relevant sectors have been key providers of talented employees (Clarysse et al., 2014). In addition, the presence of partners, customers and or suppliers is a valuable external source of knowledge for firms to be able to innovate faster than competitors (Gassmann et al., 2010). Besides commercial goals, customers open up opportunities for product improvements (Griffin and Hauser, 1993) and might play an active role in the innovation process (Afuah and Tucci, 2012).

5.2.2. Real estate attributes

Science parks as an area development provide infrastructure, facilities and services to tenant firms (e.g., Westhead and Batstone, 1999; Van Der Borgh et al., 2012; Etzkowitz and Zhou, 2017). The following real estate attributes are identified from literature: R&D facilities, supporting facilities, services and firms, shared facilities, flexibility/expansion possibilities, pricing of the facilities and services and image of the science park (see Table 31). R&D facilities provided to high-tech firms are for example laboratories, pilot plants, clean rooms and R&D equipment (Ferguson and Olofsson, 2004; Ng et al., 2019a), while services include marketing support, networking events, business support, training etc. (Westhead and Batstone, 1999; Van Der Borgh et al., 2012). In addition, services can be provided by on-site supporting firms, such as consultancy firms (Lindelöf and Löfsten, 2006; Squicciarini, 2008), patenting offices, technology transfer offices (Westhead and Batstone, 1998), governmental agencies and service companies (Van Der Borgh et al., 2012).

Table 31 Real estate attributes

Attribute description	Source
Access to R&D facilities and equipment.	Ferguson and Olofsson, 2004; Ng et al., 2019a
Range of supporting facilities, services and firms.	Westhead and Batstone, 1999; Lindelöf and Löfsten, 2006; Van Der Borgh et al., 2012
Shared facilities among different organisations.	McAdam and McAdam, 2008; Atkin and Brooks, 2009; Van Der Borgh et al., 2012; Van Winden and Carvalho, 2015
Flexibility/expansion possibilities to use additional space on the park through relocating to an existing building or through new development.	Westhead and Batstone, 1999; Lindelöf and Löfsten, 2003; Dettwiler et al., 2006
Pricing for the facilities and provided services to remain at science park are relative to total package of facilities and services acceptable.	Chan and Lau, 2005; Dettwiler et al., 2006; Van Der Borgh et al., 2012
The image/reputation of the science park as a means to promote resident organisations.	Ferguson and Olofsson, 2004; Monck and Peters, 2009; Van Der Borgh et al., 2012

Through the provision of shared facilities, firms can focus on their core business (McAdam and McAdam, 2008), gain economic advantages (Lindelöf and Löfsten, 2003; Dettwiler et al., 2006; McAdam and McAdam, 2008; Van Der Borgh et al., 2012), interact with others and contribute to information sharing or interfirm knowledge sharing (Díez-Vial and Fernández-Olmos, 2017). Furthermore, as one of the functions of a science park is stimulating the growth of new technology-based firms, it is essential that science parks provide sufficient space for novel firms (Etzkowitz and Zhou, 2017) and are flexible in additional expansion options (Westhead and Batstone, 1999; Lindelöf and Löfsten, 2003; Dettwiler et al., 2006).

Largely related to the overall science park concept is the pricing of the facilities and services. The advanced R&D facilities and the provided services by science parks have been found to be expensive for tenants compared to alternative ordinary business parks (Westhead and Batstone, 1999; Van Der Borgh et al., 2012). However, prices of facilities have been experienced to be less of an issue for new technology-based firms on science parks than similar firms not located on science parks (Dettwiler et al., 2006). For these younger firms, cost advantages are usually gained through rental subsidies (Chan and Lau, 2005). Also, Ferguson and Olofsson (2004) suggested that science park firms experience higher benefits from a positive science park image and that this benefit could partly improve their survivability. Similarly, residing at a science park with its high-quality landscaped environment, facilities and services can attract talent (Monck and Peters, 2009; Kharabsheh, 2012).

5.2.3. Managerial attributes

Science park management (when present) varies from an on-site management company, single on-site manager or informal team (Siegel et al., 2003b), although the former is more common in the European science park context (Ng et al., 2019a). The managerial attributes consist of the science park management itself and its activities: applying selection criteria, creating a communal atmosphere among tenants, providing access to regional and international networks, promoting an entrepreneurial climate and lastly providing the ease of access to new ideas, skills or knowledge on the park (Table 32).

Table 32 Managerial attributes

Attribute description	Source
An involved science park management that is active in amongst others, the daily operations, fosters interactions and networking between organisations within the park and outside.	Siegel et al., 2003b; Ratinho and Henriques, 2010; Van Der Borgh et al., 2012; Albahari et al., 2018
Science park management use selection criteria to choose new residents that contribute to the overall success and/or efficiency of the park.	Link and Link, 2003; Chen et al., 2006; Salvador, 2011; Somsuk and Laosirihongthong, 2014
Communal atmosphere on the science park fosters, trust, collaboration between firms and ultimately a community identity.	Westhead and Batstone, 1999; Van Der Borgh et al., 2012; Van Winden and Carvalho, 2015
Networking opportunities created by the science park with off-park organisations within the region for collaborative purposes, business development or financing.	Monck and Peters, 2009; Tödtling et al., 2011; Somsuk and Laosirihongthong, 2014
International networking opportunities created by the science park for collaborative purposes, business development or financing.	Saublens, 2007; Van Der Borgh et al., 2012
Promotion of entrepreneurial activity of start-up and spin-off creation and growth of new firms.	Löfsten and Lindelöf, 2005; Monck and Peters, 2009
Ease of access to new ideas, skills or knowledge of other resident organisations.	Ferguson and Olofsson, 2004; Van Der Borgh et al., 2012; Koçak and Can, 2014; Van Winden and Carvalho, 2015

Science park management is responsible for the daily operations, but also plays a pivotal role in facilitating networking within and outside the park (Link and Scott, 2003; Ratinho and Henriques, 2010; Van Der Borgh et al., 2012; Albahari et al., 2018). Moreover, science park management generally imposes selection criteria for potential future tenants. Research showed that of 82 European science parks and incubators only 2% do not have criteria in selecting resident organisations (Ng et al., 2019a).

The added value of tenant selection criteria for existing firms on a science park is the contribution to the overall success and efficiency (Somsuk and Laosirihongthong, 2014). The selection of specific firms is aimed to attract appropriate firms and therefore employees to a science park (Link and Link, 2003; Chen et al., 2006). Furthermore, clear and transparent selection policies give a certain perceived legitimacy to selected firms in the face of potential investors or customers (Salvador, 2011).

Another science park attribute that can be managed is the possible communal atmosphere on-site. Westhead and Batstone (1999) suggested that policy-makers should pay attention to measures that foster a community that is built on trust and collaboration when establishing the science park environment. Furthermore, a well-managed science park can facilitate the innovation processes on individual firm level and this in turn can create value for the community as a collective (Van Der Borgh et al., 2012). The development of communities is likely to enhance the innovation process, as ideas and knowledge can be more easily shared if people share a communal identity (Van Winden and Carvalho, 2015).

Moreover, a science park can provide for access to regional and international networks for firms. The professional network of the science park allows tenant firms to attract external investments (Monck and Peters, 2009). A part of the business development support includes access to networks for business consultation or venture capital, often in the incubator and accelerator programs (Somsuk and Laosirihongthong, 2014). The early involvement of both upstream suppliers and downstream customers within a knowledge-intensive region can speed up the innovation process of firms in certain industries (Tödtling et al., 2011). In addition, with the nature of the knowledge economy, high-tech firms are seeking international linkages for their R&D projects (Saublens, 2007). Complementarities for product innovations are often sourced globally, while partners for operational processes are sought locally by science park firms (Van Der Borgh et al., 2012).

According to Löfsten and Lindelöf (2005) incubation schemes create resources specifically for development and support of new technology-based firms in order to build an entrepreneurial environment. Alternatively, spin-offs are created through the transfer of resources of university or existing firms and also contribute to an entrepreneurial climate (Löfsten and Lindelöf, 2005; Monck and Peters, 2009). Additionally, access to research and cooperation in R&D are perceived by new technology-based firms on Swedish science parks to be advantageous for firm growth (Ferguson and Olofsson, 2004). Similarly, access to knowledge within a science park can be leveraged between synergies among resident organisations (Van Der Borgh et al., 2012).

Access to these various forms of knowledge is in line with the policy objectives of knowledge creation and technology transfer between various science park actors (European Commission, 2013). Koçak and Can (2014) found that within the Turkish context, knowledge sharing ties are most common among science park tenants, followed by joint project or product development ties. Both types of ties are related to the similarity of industrial sectors that tenants are active in (Koçak and Can, 2014). Van Winden and Carvalho (2015) posited that one of the possible synergetic effects of co-locating knowledge-intensive organisation at science parks is the ease of access to new knowledge from other organisations on park.

5.2.4. *Impact on firm performance*

The possible science park benefits technology firms can experience are explained through the results of past empiric research, which leads to the segmentation of economic, innovation and networking benefits (Albahari et al., 2010). From a policy perspective, science parks are policy tools to promote linkages between industry, research institutes and universities (Albahari et al., 2019). They belong to the highly differentiated supply-side of science, technology and innovation policy measures and should promote aforementioned networking between those actors, which would not happen otherwise (Edler and Georghiou, 2007). Additional objectives of science parks include technology transfer and the creation of an entrepreneurial climate (European Commission, 2013). The facility management literature suggests that one aspect of science parks is the use of shared facilities, which results in productive space usage for the supplier and cost savings as a benefit for the user (Atkin and Brooks, 2009). Within the science park context, the provision of university facilities to firms and subsequent cost sharing between both parties can be one of the benefits for firms to reduce initial investments and risks (Benneworth et al., 2009). However, interviews with tenants on a Dutch science park revealed that these technology firms do not perceive the cost savings from shared facilities as valuable (Van Der Borgh et al., 2012). From a knowledge-perspective, cost saving can also be vital for the promotion of innovation especially for small medium enterprises as expenses for information gathering and innovation integration have to be low for these firms (Durão et al., 2005). Similarly, knowledge spillovers between firms as a result of co-location or proximity can also lead to lower costs compared to formal agreements (Chan et al., 2011).

In the past decades, academia have been captivated by studying the possible impact of residing at a science park on the firm's performance. Empiric research has not shown uniform evidence of the science park impact on firm performance on the categories economic, innovation and networking benefits (Table 33). The pluses and minuses represent positive and negative effects respectively, while zeros indicate that those studies revealed no effect on this category. Each category consists of multiple dimensions and some authors found limited evidence within these categories. The selection of technological stronger firms by science parks has been suggested to explain the lack of contribution to innovation performance (Ramírez-Alesón and Fernández-Olmos, 2018). Moreover, Ubeda et al. (2019) suggested a moderating effect of absorptive capability, in which more experienced science park firms are more likely to report higher sales of new products as they are more able to evaluate useful knowledge. Similarly, Corrocher et al. (2019) found that on-park firms applied for more patents than off-park counterparts, but this positive effect depends on the science parks' research network and the firm's innovation capabilities.

In short, empiric research showed that evidence on economic impact is not very strong, while mixed results characterise benefits for innovative activity and there seems to be positive evidence of science parks fostering linkages between organisations.

Table 33 Empiric research on science park impact on firms

	Westhead, 1997	Colombo and Delmastro, 2002	Lindelöf and Löfsten, 2003	Ferguson and Olofsson, 2004	Fukugawa, 2006	Squicciarini, 2008	Yang et al., 2009	Chan et al., 2011	Díez-Vial and Fernández-Olmos, 2015	Vásquez-Urriago et al., 2015	Liberati et al., 2016	Vásquez-Urriago et al., 2016	Díez-Vial and Fernández-Olmos, 2017	Lamperti et al., 2017	Albahari et al., 2018	Ramírez-Alesón and Fernández-Olmos, 2018	Corrocher et al., 2019	Ubeda et al., 2019
Economic benefits																		
Attracting funding for growth/innovation		+										+						
Attracting human talent		+		0								0						
Increased sales				0					+	+	+	0		0	+	0		+
Increased profitability											0	0						
Cost saving*																		
Innovative benefits																		
New patents/licenses		0	0			+	+				0		+	+	+		+	
New products/services	0	0	0						+	+						0		+
Increased research contracts					+													
Increased R&D investments	0				+		+					0		+				
Networking benefits																		
Develop ties with other firms			-					+					+					
Develop ties with research institutes									+			+						
Develop ties with university		+			+				+			+	+					

Note. *cost savings was not used explicitly as a performance indicator, but as a general benefit (e.g., Durão et al., 2005; Benneworth et al., 2009; Chan et al., 2011).

To summarise, the majority of beneficial performance dimensions are derived from empiric science park research comparing on-park with off-park firms. Firstly, economic benefits that firms perceive include attracting funding for growth/innovation, attracting human talent, increased sales of new products (new to the organisation and new to the market), increased profitability, and also cost savings. Secondly, innovation benefits are new patents/licenses, new products/services, increased research contracts, and increased R&D investments. Lastly, networking benefits, are developing formal and informal ties (e.g., joint research contracts, social networking) with other firms, research institutes or the university.

5.3. Survey, sampling and methods

5.3.1. Structure of the online interview

The means-end theory suggests that products possess attributes that are seen as means by consumers to reach certain ends. The product attributes, in this case the science park, embody 'what' users choose, while benefits that are linked with these attributes are the reason 'why' they choose to locate on the science park (Dellaert et al., 2014). For this explorative study the Association Pattern Technique (APT) is adapted through an online interview among science park tenant firms. Ter Hofstede et al. (1998) proposed the APT as a quantitative approach that complements qualitative 'soft laddering' techniques, where respondents are restricted by interviewers as little as possible and ladders (i.e., means-end links) are produced afterwards by the researcher. In contrast, with 'hard' laddering, interviewers inquire respondents on each 'ladder' one-by-one directly and requires a priori lists of possible attributes (means) and benefits (ends) relevant to the respondents. The traditional 'soft' laddering technique used in means-end data collection is a recall technique, which is not intended for large-scale data collection as it is generally more time consuming and moreover, requires skilled interviewers (Ter Hofstede et al., 1998). The authors showed that APT is appropriate for large-scale surveys and, hence, allows quantitative analysis of the obtained data.

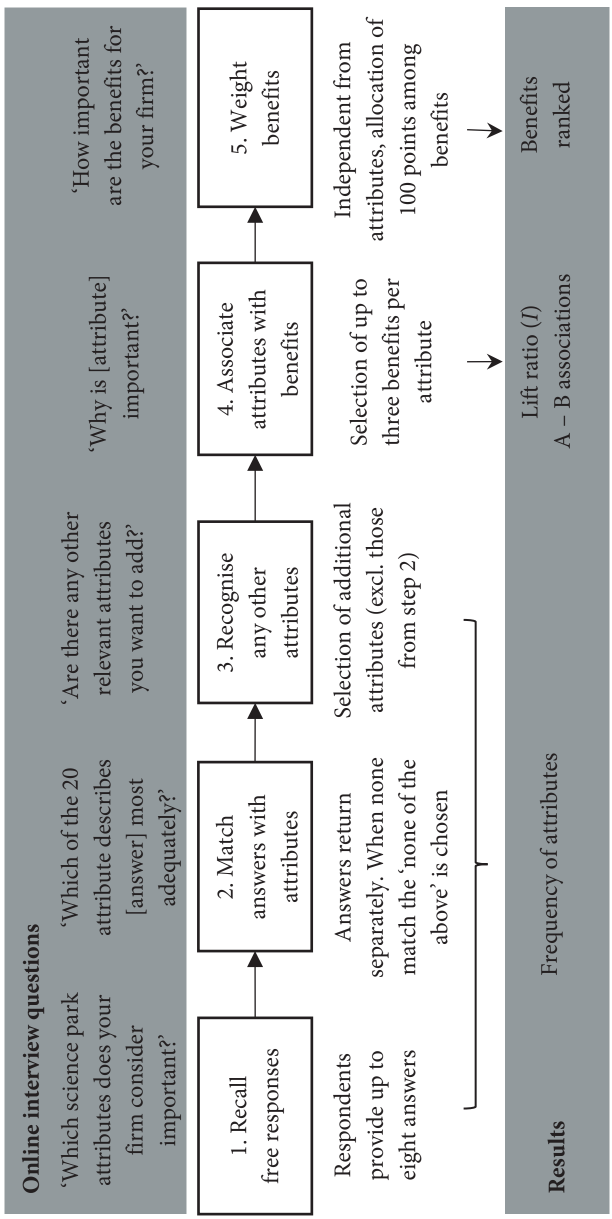
Within laddering interview protocols, attributes, benefits, values and the relationship between these aspects are elicited from respondents. The core principle of APT includes the association between attributes and benefits, but excludes higher level values and objectives. It is argued that in decision-making processes values remain stable among individuals and that these values are less related to the product itself (Wendel and Dellaert, 2005). The current approach is a combination of both 'soft' and 'hard laddering', because on the one hand free responses are elicited and on the other hand these free responses are matched with an a priori defined list of attributes. In this manner, respondents are free to mention any relevant attributes without the restriction nor influence of only using a predefined list. After some initial questions on job position and firm characteristics, the main interview consists of five steps: 1) recall, 2) match, 3) recognise, 4) associate and 5) weight.

First within the recall step, respondents are asked to mention up to eight attributes they perceive as important that add value to their organisation. Within the online interview, respondents provide their answers in up to eight empty text boxes. In this way, respondents have freedom to recall their most important attributes. In the second step, respondents are asked to match their initial elicited attributes one-by-one with the list of twenty science park attributes from the literature review. This step is included to allow respondents to combine their exact free responses with the a priori list. A 'none of the above' is included for elicited answers that cannot be matched with the science park attributes.

Next in the recognise step, respondents are presented with the a priori list of science park attributes and are asked to select additional science park attributes, if any, they deem important (earlier selected attributes are excluded). In the fourth step, each attribute is separately returned and respondents are asked why this specific attribute is important, through selecting associated benefits (up to three benefits per attribute). The respondent indicates which benefits relate to a certain attribute, which results in binary observations for each A-B-link (Ter Hofstede et al., 1998). Horeni et al. (2008) noted that presenting all attributes and benefits simultaneously is complex and respondents might even struggle with the load of information. In this case, all twelve benefits are presented with one preselected attribute at a time to reduce the abundance of information (an option for own input for benefits is also included).

In the final phase, respondents are first asked which benefits are relevant to them independent from attributes and then inquired to distribute 100 points among those selected benefits based on importance. This preselection of benefits is included as a way to relieve respondents, because allocating points to more than eight options is very challenging (Mooi and Sarstedt, 2014). Another ranking technique, Analytical Hierarchy Process is not considered as with twelve benefits, 66 pairwise comparisons are to be evaluated by each respondent. The importance of each benefit is determined directly through summing all scores of each benefit divided by the total number of points allocated by all respondents. The resulting weights ranging between 0 and 100 for each of the benefits provide insight into the mean importance ranks of the benefits across all respondents. As a result of the subjective comparison among benefits, the produced average scores across all respondents should be treated as an ordinal scale (Smith and Albaum, 2005). This direct approach of ranking benefits is used to produce a top 5 of important perceived benefits according to the respondents. Graphical overviews are created through the frequency of attributes (both for 'recalled' and 'recognised' attributes), association strength (lift ratio, I as explained in subsection 5.3.3) and top 5 benefits (constant sum). These graphical overviews give insight in how the most important perceived benefits are attained through which attributes and how relevant each attribute is.

Figure 4 summarises the steps in the interview regarding the elicitation of science park attributes and perceived benefits. The top part lists the interview questions asked at each step and the bottom part shows the results derived from each step.



Note. The exact free responses are returned to respondents in stages two and four.

Figure 4 Overview of interview questions and derived results

5.3.2. Sampling of firms and sample characteristics

The sample frame are the science park firms on twelve science parks in the Netherlands. The science parks of interest are based on the science park typology of Ng et al. (2019a). According to this typology similarities of these science parks include the presence of research institutes, either university or university-related organisations and firms of all business development phases. Aside from general business support facilities, all locations provide tenants with shared facilities, in the form of R&D space, work-related facilities and services. Dissimilarities among the twelve science parks relate to the technology sectors present, the ownership model (i.e., university-owned, privately and/or publicly owned) and the physical size of each location. The science park management organisations of these twelve science parks are contacted to distribute the online interview among their tenant firms.

Ten of the twelve approached science park management organisations agreed to distribute the online interview among their park tenant firms. The ten science parks that participated in this data collection are: Amsterdam Science Park (Amsterdam), Automotive Campus (Helmond), Brightlands Chemelot Campus (Sittard-Geleen), Kennispark Twente (Enschede), Leiden Bio Science Park (Leiden), Novio Tech Campus (Nijmegen), TU Delft Science Park (Delft), TU/e Campus (Eindhoven), Utrecht Science Park (Utrecht) and Wageningen Campus (Wageningen). In contrast, Campus Groningen (Groningen) and High Tech Campus Eindhoven (Eindhoven) declined participation. As the main aim of this study is to explore the associations between attributes and benefits, the unit of analysis is positioned at the level of associations. The pretention is therefore not to generalise all findings towards the hosted science park firms or all firms in the Netherlands. Within these science parks, the main decision-makers of the hosted science park firms are recruited to be the respondents, such as the Chief Executive Officer (Hambrick 2007).

The survey was hosted online between March and June 2018 for a three months period. In total 51 online interviews were completed by respondents working at Dutch science park firms. Those that participated in the questionnaire are relevant decision-makers as the majority is active in either C-level or managerial functions (see Table 34). Furthermore, the majority of firms are located at university-owned science parks and are relatively small to medium-sized organisations. A wide spread among new and established firms is present as the average firm age in years is 21.25 with a standard deviation of 33.51 years. Moreover, the duration of stay on the respective parks is 7.46 year on average with a SD of 12.94. In terms of sectors, a large group of responding firms are active in Bio/medtech and life sciences and Computer and software engineering or operates as Service companies.

Table 34 Characteristics of 51 science park tenant firms

	n	%		*n*	%
Respondent job position			Sectors*		
Chief Officer (E, T, I, O)	24	47	Aerospace and transportation	7	5
Manager (general, R&D, facility)	17	33	Agriculture and forestry	2	1
Others	10	20	Bio/medtech and life sciences	22	16
			Chemistry and new materials	15	11
Science park location			Civil and construction engineering	3	2
University science park	38	75	Computer and software engineering	14	10
Non-University science park	13	25	Electronics (nano electronics)	4	3
			Energy and environmental technology	5	4
Size on park (employees)			Food sciences	3	2
Less than 10	31	61	Industrial manufacturing	5	4
Between 10 - 50	11	22	Internet technologies	7	5
Between 50 - 250	2	4	Mechatronics	3	2
More than 250	7	14	Micro- and nanotechnology	4	3
			Optics	4	3
Spinoffs			Robotics and automation	3	2
Corporate spin-off	5	10	Sensors and instrumentation	7	5
University spin-off	13	25	Service company	16	12
Not a spin-off	33	65	Other sectors	10	7

Note. *Respondents were allowed multiple options.

5.3.3. *Association rule approach*

Within the data mining literature, the association between two separate items can be interpreted as an association rule of an antecedent item leading to a consequent item (Tan et al., 2006). Following this, the rule of $A_i \rightarrow B_j$ is adopted, where *i* represents one of the attributes and *j* one of the benefits. In this case, all possible A_i - B_j associations are considered as binary variables. A_i - B_j links are calculated separately to gain insight in the association strength between attributes and benefits selected by respondents. The conditional probability of B_j given A_i can therefore be calculated where a high $P(B_j|A_i)$ means that B_j will likely to be selected knowing that A_i is already chosen. However, only a high conditional probability is sometimes insufficient. As it does not consider the base probability of B_j and the inverse relation of an attribute that is not associated with a benefit. Therefore, the lift ratio (*I*) is used to compare the probability of a benefit in conjunction with an attribute (the conditional probability B_j given A_i) and the sole probability of that benefit.

Moreover, when inferring the rule of ($A_i \rightarrow B_j$), the lift ratio reveals the strength of the association (Tan et al., 2006). Formally, the lift ratio is defined as:

$$Lift\ ratio\ (I)\left(A_i \rightarrow B_j\right) = \frac{P(B_j|A_i)}{P(B_j)} = \frac{P(A_i,B_j)}{P(A_i)P(B_j)} \begin{cases} > 1, if\ A_i\ and\ B_j\ are\ associated \\ \leq 1, if\ A_i\ and\ B_j\ are\ not\ associated. \end{cases} \quad (1)$$

In words, if the lift ratio has a value larger than one, then the occurrence of both antecedent A_i and consequent B_j depend on each other and the presence of A_i will increase the likelihood of the presence of B_j. If the lift ratio of A_i - B_j is equal or lower than one, then the presence of A_i does not increase the probability of occurrence of B_j meaning that there is no association. In the equation of the lift ratio, the base probability of a benefit is included in the denominator, which means that lift ratios with the same benefit can be compared mathematically. The lift ratio allows for the determination of the association strength on attribute and benefit level. Attribute-benefit associations with lift ratios higher than one suggest that the attribute is a means towards the benefit, while attributes within links with values equal or lower than one are not perceived to be contributing to attaining those perceived benefits. A cut-off point of strong A_i - B_j association is used to highlight interesting associations ($I > 1.5$).

5.4. Results

In this section the findings derived from the online interview on associations between science park attributes and perceived benefits are discussed. Firstly, the recalled and recognised attributes by the 51 tenant firms from Dutch science parks are described. Secondly, the association matrix is presented listing the conditional probabilities of benefits within the context of attributes. Then the most important benefits are discussed derived from the constant sum allocation of points by respondents. Finally, these important perceived benefits are then further explored through the association strength with the selected science park attributes (lift ratio). The results indicate in what frequencies science park attributes are mentioned by respondents and how these science park attributes are associated with the most important perceived benefits.

5.4.1. Recalled and recognised science park attributes

In the first step, the 51 respondents recalled 224 science park-related attributes that were deemed important for their organisation (Table 35). These entries were recalled from memory as respondents entered their relevant attributes into the text boxes within the online interview. On average each respondent gave 4.49 responses (SD 1.76), which shows that the maximum number of eight responses was not used often. Among all 224 entries only 21 attributes were initially classified by respondents into the 'none of the above' answer. Subsequently, three researchers independently examined these 21 entries and assigned five of these to existing attribute categories. As indicated in Table 35 the remaining 16 attributes were categorised as 'location', because these entries are largely related to either specific cities, transportation or accessibility attributes. Looking at the three categories, the most recalled attributes are related to science park real estate, followed by managerial attributes and lastly the proximity attributes. On attribute level, the top five most frequently recalled attributes are: 1) proximity to university, 2) supporting facilities, service and firms, 3) shared facilities, 4) entrepreneurial climate and lastly both 5) R&D facilities and location are mentioned equally frequent. In the third step, respondents were asked if any of the other listed attributes are also important for their organisation based on recognising them from the list of twenty attributes. Respondents selected relatively more attributes compared to the first step as there were no restrictions on the number of options (mean 5.25, SD 2.91). For each respondent, recognised attributes did not include earlier recalled attributes from the initial step.

Table 35 Frequencies of recalled and recognised science park attributes

	Attributes	Recalled		Recognised		Recalled + Recognised	
			% of *n*		% of *n*	% of *n*	% of total attributes
P	Proximity to university	30	59%	14	27%	86%	28%
	Proximity to similar firms	12	24%	15	29%	53%	
	Proximity to research institutes	8	16%	16	31%	47%	
	Proximity to new customers	2	4%	13	25%	29%	
	Proximity to well-known firms	3	6%	10	20%	25%	
	Proximity to existing customers	3	6%	9	18%	24%	
	Proximity to competitors	0	0%	2	4%	4%	
R	Supporting facilities, services and firms	26	51%	15	29%	80%	37%
	Shared facilities	21	41%	16	31%	73%	
	Flexibility/expansion possibilities	12	24%	17	33%	57%	
	Image / reputation of science park	12	24%	14	27%	51%	
	Pricing	9	18%	16	31%	49%	
	R&D facilities	16	31%	8	16%	47%	
M	Entrepreneurial activity	18	35%	17	33%	69%	32%
	Access to regional networks	14	27%	18	35%	63%	
	Communal atmosphere	7	14%	20	39%	53%	
	Access to international networks	4	8%	17	33%	41%	
	Access to new knowledge	8	16%	12	24%	39%	
	Science park management	3	6%	16	31%	37%	
	Selection criteria new firms	0	0%	3	6%	6%	
O	Location	16	31%	0	0%	31%	3%
	Total (*n* = 51 firms)	224		268		492	100%

Table 35 (column Recognised) shows on attribute level that among others the frequency is larger compared to the recall step of proximity to university, proximity to well-known firms, proximity to new customers, science park management, communal atmosphere and access to international network. In the last column both recalled and recognised attributes are listed together. The 1) proximity to university is most frequently mentioned, followed closely by 2) supporting facilities, 3) shared facilities, 4) entrepreneurial climate and lastly 5) access to new knowledge from other resident organisations. Within the recall step, R&D facilities was the fifth most-mentioned attribute, while in the recognise step this attribute was selected less often than other attributes.

In order to explore the relationships among science park attributes, the Pearson correlation test was used to seek attributes with potential synergies among each other. Table 36 shows all attributes that are significantly correlated. ‘Proximity of university’ was mentioned often in conjunction with other managerial attributes, suggesting that some synergies exist with this type of organisation with gaining access to networks, entrepreneurial climate and gaining new knowledge. In terms of synergies among attributes, the university seem to serve a different role as research institutes, as the latter is more frequently mentioned with firm-related proximity attributes. As expected tenant firms perceived a strong synergy between proximity to new and existing customers as both attributes could lead to more business directly. Moreover, the strong correlation between ‘science park management’ and ‘communal atmosphere’ suggests that both attributes are mentioned in conjunction as important aspects. The question arises whether this management function is mandatory or beneficial for creating a communal feeling. Lastly, the ‘access to international networks’ is most often times correlated with other proximity attributes, which suggests that science park tenant firms perceive synergies through the proximity of different type of organisations to gain access to business relations from abroad.

Table 36 Correlation science park attributes

Attributes	University	R institute	SimiF	WellknF	Competitors	Newcust	Exiscust	Flex/exp	Pricing	SP manag	Selection
WellknF		.409**									
Competitors		.387**		.345*							
Newcust					.313*						
Exiscust						.555**					
Supfac			.410**								
Flex/exp							.296*				
Pricing			.391**								
SP manag				.294*					.278*		
Community								.343*		.449**	
Intnetwork	.304*	.283*		.309*		.310*					.277*
Entrepreneur	.316*										
Newknow	.296*									.279*	

Note. Significant on p = 0.05* or 0.001** level (2-tailed).

Table 37 Conditional probabilities perceived benefits given attributes

	Attributes	Fund	Human	Sale	Profit	Cost	Patent	Product	Research	RDinv	TieF	TieR	TieU	Other	N (total)	P(A)
Proximity	University	10%	25%	1%		4%	2%	14%	4%	4%	4%	5%	23%	3%	97	10%
	R institutes	13%	13%	4%		4%	4%	20%	2%		4%	28%	4%	6%	54	5%
	SimiF	5%	16%	5%	2%		2%	20%	7%	3%	28%	8%	2%	3%	61	6%
	WellknF	4%	15%	7%	4%		4%	15%	4%	7%	33%	7%			27	3%
	Competitors			25%				50%			25%				4	0%
	Newcust	6%		33%	6%	3%		12%	15%		21%			3%	33	3%
	Exiscust	6%	3%	23%	16%	10%		13%	6%	3%	10%	3%	3%	3%	31	3%
Real estate	RDfac	4%	2%		2%	33%	4%	17%	2%	13%	4%	4%	4%	9%	46	5%
	Supfac	6%	16%	4%	6%	30%	1%	9%	1%	1%	10%	1%	3%	11%	70	7%
	Sharedfac		7%	2%	5%	44%	4%	7%	5%	2%	7%	4%		13%	55	5%
	Flex/exp	4%	17%	2%	6%	27%		15%		8%	6%	2%	2%	12%	52	5%
	Pricing	2%	5%	5%	19%	50%		5%		5%	2%		2%	5%	42	4%
	Image	20%	23%	8%	2%	2%			7%	3%	17%	12%	5%	2%	60	6%
Managerial	SP manag	4%	4%	4%		2%	4%	13%	2%	4%	24%	13%	15%	9%	46	5%
	Selection													100%	3	0%
	Community	4%	18%	5%		4%		2%			29%	20%	14%	5%	56	6%
	Regnetwork	23%	8%	8%		5%		8%	8%	3%	23%	5%	5%	8%	40	4%
	Intnetwork	17%	12%	13%	2%	4%		12%	10%	2%	15%	8%	4%	2%	52	5%
	Entrepeneur	13%	16%	9%	3%	1%	3%	17%	3%	1%	24%	3%	5%	3%	76	8%
	Newknow	7%	4%	12%	3%	3%	8%	25%	5%	3%	20%	8%	4%		76	8%
	Location	3%	35%	3%		13%		3%		3%	10%	3%		26%	31	3%
	P(B)	8%	13%	7%	3%	12%	2%	13%	4%	3%	15%	7%	6%	6%	100%	100%
		84	134	71	34	120	21	128	41	33	150	73	61	62	1,012	

5.4.2. Attribute and benefit associations and importance perceived benefits

For each selected attribute, respondents were asked which benefits are related to their selection. For each attribute up to three benefits could be selected. The total of 492 recalled and recognised attributes led to 1,012 attribute – benefit associations. Table 37 shows the conditional probabilities of the various benefits (B_j) within the context of the different attributes (A_i).

The three attributes most frequently associated with benefits are proximity to university, entrepreneurial climate and ease of access to new ideas, skills or knowledge from other resident organisations. Access to new knowledge (8%) is more often associated with more than one benefit at a time, while for instance support facilities (7%) is often associated with relatively fewer benefits (support facilities is the second-most frequent recalled and recognised attribute). Proximity to competitors and selection criteria of new resident organisations are associated with benefits the least. Looking at the conditional probabilities, the real estate attributes are primarily associated to economic benefits with conditional probabilities of more than 40% between these two groups. For proximity and managerial attributes, a wider distribution among the benefit groups is visible. In terms of benefits, the most mentioned one is developing ties with other firms, followed by attracting human talent, new product/services, cost saving and attracting funding for growth. The least associated benefits are new patents/licenses, increased R&D investments and increased profitability. Furthermore, respondents were asked to allocate 100 points among relevant benefits based on importance independent from attributes. Higher points indicate a higher importance for the organisation. The total points allocated to each benefit is divided by the total points allocated by all respondents. Table 38 lists the perceived benefits ordered on importance and the rank of each benefit in terms of frequency of associations with attributes.

Table 38 Importance rank benefits

Benefit	Constant sum rank*	Rank in association
Attracting human talent	**1. (18)**	**2.**
Increased sales	**2. (13)**	**7.**
Cost saving	**3. (12)**	**4.**
Attracting funding for growth/innovation	**4. (12)**	**5.**
Develop ties with other firms	**5. (10)**	**1.**
New products/services	**6. (10)**	**3.**
Develop ties with university	7. (8)	9.
Develop ties with research institutes	8. (5)	6.
New patents/licenses	9. (4)	13.
Increased profitability	10. (4)	11.
Increased research contracts	11. (2)	10.
Increased R&D investments	12. (2)	12.
Others	13. (1)	8.

Note. *constant sum scores in parentheses.

The most important perceived benefit is attracting human talent, followed by increased sales, cost saving, attracting funding for growth/innovation and developing ties with other firms and new products/services. The top five most associated benefits are found within these six most important perceived benefits. An exception is the increased sales, which was less often associated with science park attributes. As the ranking of developing ties with other firms and new product/services are similar in scores, the top six important benefits are used in the following discussion on association strength.

5.4.3. Lift ratios science park attributes and benefits

The attributes that are perceived as the most relevant for supporting the most important benefits based on the constant sum ranking are explored through the lift ratio. Next, for each of the three attribute groups, proximity, real estate and managerial attributes a graphical overview is shown in order to provide insight in which attributes are associated with which benefits. In the figures the attributes are scaled to the number of times a specific attribute is recalled and recognised by science park firms as relevant for their organisation. The links are scaled to the lift ratios of attributes and benefits. Within the figures only the links with value 1.5 or higher are shown, which indicates a strong association between attribute and benefit. The lift ratios between all science park attributes and perceived benefits can be found in Table 39. Within the figures, the six most perceived benefits are scaled to the constant sum scores.

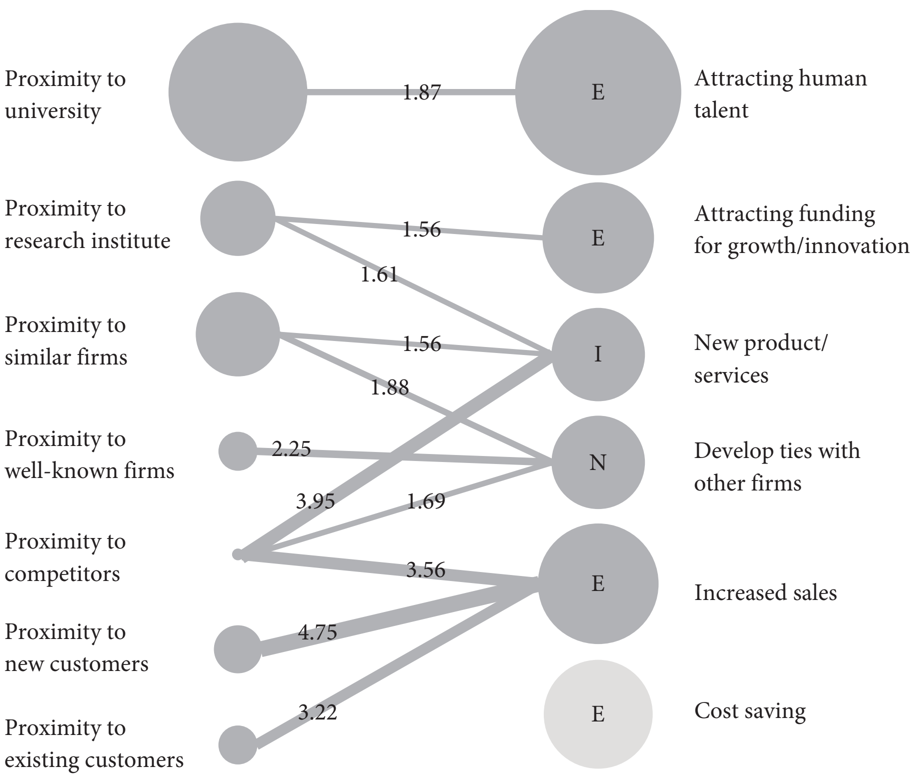
Table 39 Lift ratios science park attributes and benefits

Attributes	Fund[4]	Human[1]	Sale[2]	Profit[10]	Cost[3]	Patent[9]	Product[6]	Research[11]	RDinv[12]	TieF[5]	TieR[8]	TieU[7]	Other[13]
University	1.24	1.87	0.15		0.35	0.99	1.14	1.02	1.26	0.28	0.71	3.76	0.50
R institutes	1.56	0.98	0.53		0.31	1.78	1.61	0.46		0.25	3.85	0.61	0.91
SimiF	0.59	1.24	0.70	0.49		0.79	1.56	1.62	1.01	1.88	1.14	0.27	0.54
WellknF	0.45	1.12	1.06	1.10		1.78	1.17	0.91	2.27	2.25	1.03		
Competitors			3.56				3.95			1.69			
Newcust	0.73		4.75	1.80	0.26		0.96	3.74		1.43			0.49
Exiscust	0.78	0.24	3.22	4.80	0.82		1.02	1.59	0.99	0.65	0.45	0.54	0.53
RDfac	0.52	0.16		0.65	2.75	2.10	1.38	0.54	4.00	0.29	0.60	0.72	1.42
Supfac	0.69	1.19	0.61	1.70	2.53	0.69	0.68	0.35	0.44	0.67	0.20	0.47	1.87
Sharedfac		0.55	0.26	1.62	3.68	1.75	0.58	1.35	0.56	0.49	0.50		2.08
Flex/exp	0.46	1.31	0.27	1.72	2.27		1.22		2.36	0.39	0.27	0.32	1.88
Pricing	0.29	0.36	0.68	5.67	4.22		0.38		1.46	0.16		0.40	0.78
Image	2.41	1.76	1.19	0.50	0.14			1.65	1.02	1.12	1.62	0.83	0.27
SP manag	0.52	0.33	0.62		0.18	2.10	1.03	0.54	1.33	1.61	1.81	2.52	1.42
Selection													16.32
Community	0.43	1.35	0.76		0.30		0.14			1.93	2.72	2.37	0.87
Regnetwork	2.71	0.57	1.07		0.42		0.59	1.85	0.77	1.52	0.69	0.83	1.22
Intnetwork	2.09	0.87	1.92	0.57	0.32		0.91	2.37	0.59	1.04	1.07	0.64	0.31
Entrepeneur	1.59	1.19	1.31	0.78	0.11	1.27	1.35	0.65	0.40	1.60	0.36	0.87	0.43
Newknow	0.79	0.30	1.69	0.78	0.22	3.80	1.98	1.30	0.81	1.33	1.09	0.65	
Location	0.39	2.68	0.46		1.09		0.26		0.99	0.65	0.45		4.21

Note. Strong associations highlighted ($I > 1.5$). Benefits are indexed on rank order of constant sum scores.

5.4.3.1. Perceived benefits of proximity attributes

Looking at the proximity attributes, the following results can be derived (see Figure 5). The most important benefit, attracting human talent, is strongly associated with the most frequently recalled and recognised proximity to university attribute. This is in line with past studies, in which the role of the university has been highlighted as a means for search opportunities for human talent (McAdam and McAdam, 2008).



Note. Left hand side: attributes scaled to the number of occurrences.
Middle: links scaled to the lift ratio (*I*) greater than 1.5.
Right hand side: benefits scaled to the number allocated points.

Figure 5 Overview of associations between proximity attributes and benefits

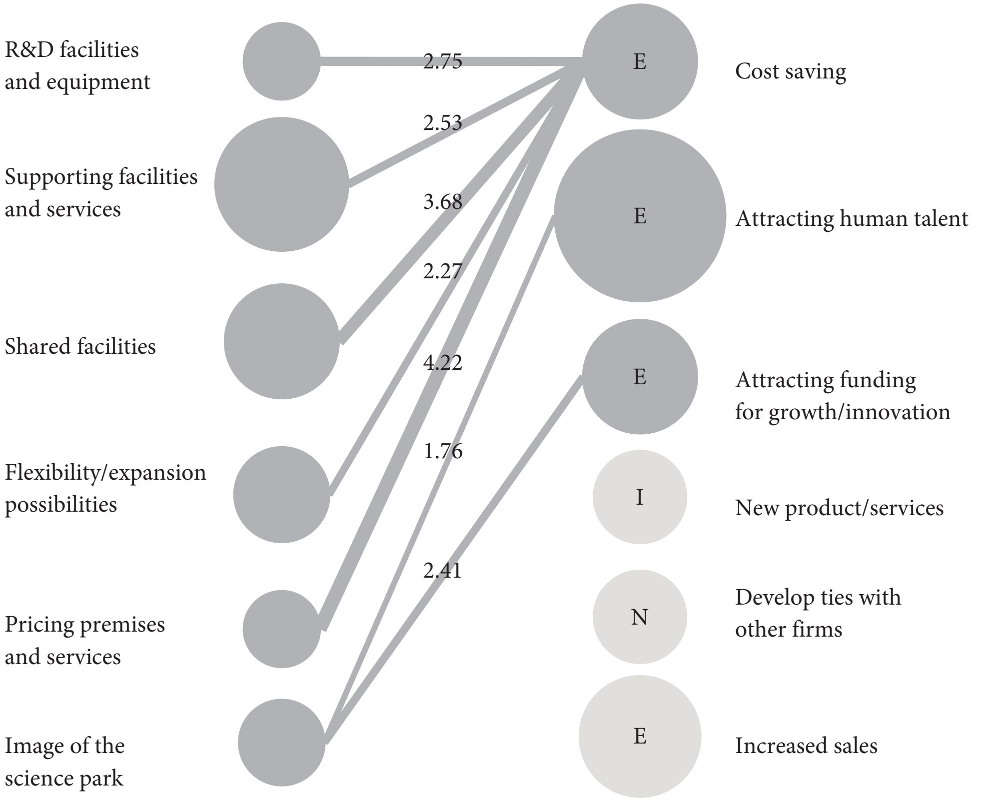
Being near research institutes is for science park firms also a means for attracting funding for growth/innovation and new products/services. The association between attracting funding and the proximity of research institutes can be explained through the R&D investment climate within the Netherlands. While the Netherlands Organisation for Scientific Research (NWO) stimulates joint research projects between the public and the private sector on certain technological fields, private businesses invest less directly in R&D than similar innovation systems (OECD, 2014). Developing new product/services is also associated to the proximity to similar firms and proximity to competitors. Being closely located to similar firms provides for competitive or collaborative opportunities for innovative projects (Lamperti et al., 2017). The perceived link between new innovative output and the proximity of research institutes has been suggested to also lead to more patenting activity and R&D investments (Lamperti et al., 2017).

As expected, developing ties with other firms is associated with all three firm-related proximity attributes. The second most important perceived benefit, increased sales, is associated to the proximity to competitors, new and existing customers. Proximity to university is not associated with increased sales. In contrast, Ferguson and Olofsson (2004) found that young science park firms who reported collaboration with universities tend to have more sales, although with a high variation. This could be explained by the presence of both strong performing and weaker firms in different business development phases (Ferguson and Olofsson, 2004).

Moreover, in line with Vásquez-Urriago et al. (2016), the benefit increased sales is not found through collaborative efforts from science park firms with knowledge-intensive partners. Vásquez-Urriago et al. (2016) suggest that especially economic advantages are gained with the passing of time. The high standard deviation of both 'duration of stay' and 'firm age' further underlines the wide range of firms active in different business development phases on Dutch science parks. It has to be noted, that among all attributes, competitors is one of the least mentioned attribute. Overall, multiple proximity attributes are strongly associated by tenant firms with economic (increased sales), innovation (new products/services) and networking benefits (develop ties with other firms). Cost saving is not associated as a benefit of proximity attributes. This suggests that knowledge spillovers between co-located partners is not perceived as a cost advantage, while more formalised and expensive knowledge transfers (i.e., research contracts) are likely to be more abundant (Chan et al., 2011).

5.4.3.2. Perceived benefits of real estate attributes

In terms of real estate attributes, the majority of attributes are strongly associated with cost saving (Figure 6). This is in line with Durão et al. (2005) and Benneworth et al. (2009) in which cost saving derived from infrastructure could free up resources to promote innovation. Especially for new technology-based firms who are fine-tuning their products for a commercial launch, cost benefits derived from real estate is important (Chan and Lau, 2005). This demonstrates that according to tenant firms the overall economies of scale derived from shared facilities and services are known to them.



Note. Left hand side: attributes scaled to the number of occurrences.
Middle: links scaled to the lift ratio (*I*) greater than 1.5.
Right hand side: benefits scaled to the number allocated points.

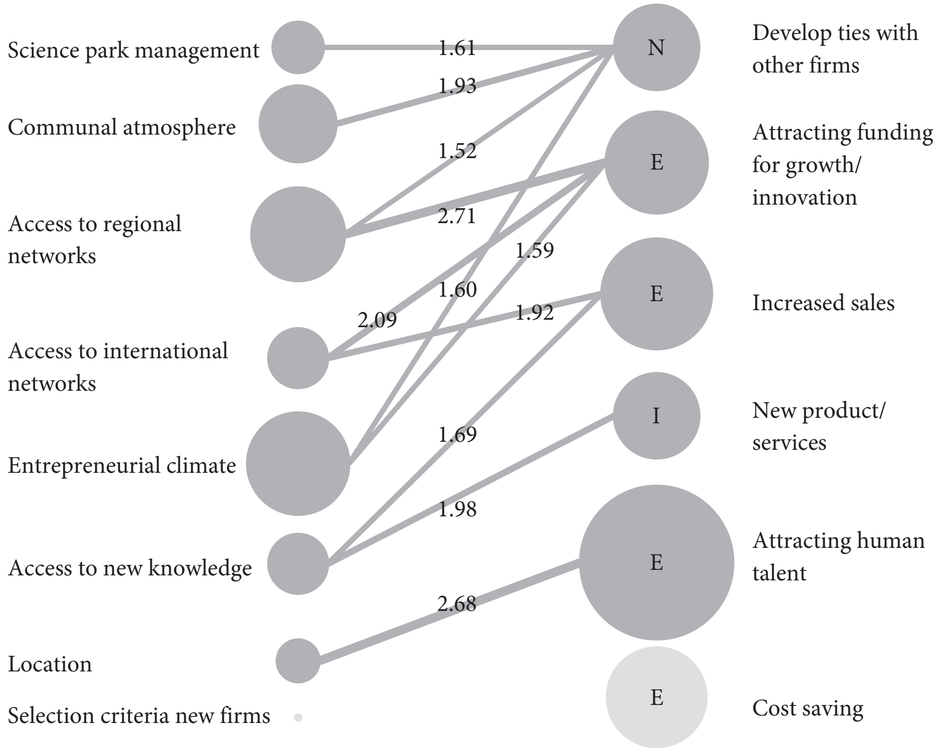
Figure 6 Overview of association between real estate attributes and benefits

A sole exception is image of the science park, which is the only real estate attribute that is strongly associated with attracting human talent and attracting funding for growth/innovation. Science park image has been suggested to provide for legitimacy for new firms (Ferguson and Olofsson, 2004). Cadorin et al. (2017) argued that inexplicitly science parks are actively attracting human talent through enticing key staff members to start-ups, creating international allure and collaboration with regional universities. Chan and Lau (2005) posit that science park image might be beneficial in business negotiations, which will be beneficial in attracting funding from external parties. These results indicate that science parks succeed in communicating this positive image towards tenant firms.

In general, all real estate attributes are strongly associated with economic benefits, with no strong associations measured between these attributes and new products/services, develop ties with other firms and increased sales. Strikingly, both shared facilities and support facilities are not associated with developing relations between firms, even though these attributes provide opportunities for users to meet others.

5.4.3.3. Perceived benefits of managerial attributes

Regarding managerial attributes are strongly associated with all three types of benefits (see Figure 7). The results show that science park management, communal atmosphere, access to regional networks and entrepreneurial climate play a positive role in developing ties with other park firms. Tenant firms perceive science parks not as isolated objects within its own region. As science parks should be part of wider university-government-industry system (Etzkowitz and Zhou, 2017).



Note. Left hand side: attributes scaled to the number of occurrences.
Middle: links scaled to the lift ratio (*I*) greater than 1.5.
Right hand side: benefits scaled to the number allocated points.

Figure 7 Overview of association between managerial and other attributes and benefits

Entrepreneurial climate and both access to regional and international networks are strongly associated with attracting funding for growth/innovation. Attracting funding through the access to regional and international networks is in line with Koçak and Can (2014), as tenants who receive R&D investments are more likely to have linkages external to the park. Furthermore, the access to international networks and the ease of access to new knowledge of other resident organisations are also considered as means to increase sales. The most important benefit, human talent, is most strongly associated with the attribute category 'location', which is related to specific cities or accessibility. Large cities are known to be attractive for talented knowledge workers (Storper and Venables, 2004; Florida, 2014). This attribute category was initially not included within the a priori list of attributes. Location is added as multiple respondents indicated that none of the attributes from literature matched with their free responses. Therefore, this attribute embodies only a small fraction of the total number of selected attributes. None of the managerial attributes are strongly associated with cost saving and selection criteria are not perceived as strongly associated with any benefits.

5.5. Discussion

The aim of this study was to explore the perceived benefits science park firms associate with specific science park attributes, which provides insights for science park configurations that align to needs of tenant firms. On benefit level, the majority of the most important benefits belong to the economic category. These benefits were derived from performance indicators used in existing science park evaluation research. Among the top 6 most important benefits perceived by tenant firms some have gained much attention from researchers (i.e., 'increased sales' and 'new products/services'). However, the current study reveals that other perceived benefits are also important for the tenant firms, including 'attracting human talent', 'attracting funding for growth/innovation', 'develop ties with other firms', and 'cost saving'. The literature review showed that these performance indicators have received only some to no attention from science park evaluation research. In particular, cost saving has not been included as a science park performance indicator at all in the past decades. In contrast, existing research has focused heavily on the performance indicator: 'new patents/licenses', while tenant firms perceived this aspect as relatively less important. Logically, they valued 'new products/services' as more important as this is related to more tangible financial resources.

Furthermore, the results indicate that specific attribute groups serve different perceived benefits. Tenant firms associated proximity and managerial attributes with all three categories of economic, innovation and networking benefits, while the majority of real estate attributes are associated only with economic benefits. On attribute level, the majority of the associations found are in line with previous evaluative research through a novel demand-driven approach. However, results show remarkable absent links within the perception of tenant firms, which has implications for the science park literature and management in practice.

Especially interesting is the absence of the link between the networking benefit and any of the real estate attributes as there is a large body of work on social interaction and knowledge transfer between co-located actors (e.g., Storper and Venables, 2004; McAdam and McAdam, 2008).

Boschma (2005) argued that physical proximity and socialisation between actors are only some of the factors that enhance innovation as other proximity dimensions are also influential. It appears that in the perception of tenant firms that although they can be physically close to one another, there could be some social, cognitive, organisational or institutional distance between them in order to share knowledge. The findings are in line with Chan and Lau (2005), but their incubator context is extended to the science park level. Similarly, they found that technology-based firms do not interact with each other within the non-territorial spaces. Chan and Lau (2005) posited that tenants have nothing in common in terms of business, product or market-related topics, which could be a sign of cognitive or organisational distance (Boschma, 2005). The finding that tenant firms do not perceive the offered support for interaction via real estate attributes (i.e., shared facilities or supporting facilities and services) to be meaningful for networking benefits is a significant message towards science park management. A possible explanation besides distance obstacles might be that co-location and interacting with other firms occur someplace else or that the link between those attributes and networking and to enhance innovation performance is not (yet) apparent. Tenants do not associate co-location with knowledge transfer, which suggests that science park management should strengthen their effort in building trust or matching cognitive and organisationally similar firms on science parks. Although as the results demonstrate, the networking role of the science park management has already been acknowledged by tenants.

The absence of the association between science park management and developing new products/services can be explained by science park governance models. These models are largely tied to the governing body and the possible commercial or scientific objectives. From a commercial perspective, science park management when operated as an autonomous entity separate from governments or university with a risk-seeking mentality might speed up the innovation process for tenant firms (Kharabsheh, 2012). While the value of university-managed science parks for firms is the potential access to the knowledge created at the university. However, Albahari et al. (2017) posit that additional effort is required for commercialising knowledge into innovations. The majority of firms in the sample is located on university-owned science parks, which might lack that risk-seeking mentality from the science park management that accelerates the innovation process. This could explain why science park management is only associated with developing ties with other firms, but not to enhanced innovations. Moreover, according to Vásquez-Urriago et al. (2016) science park firms are more likely to collaborate in innovation than off-park counterparts, but the role of the science park management within this process remains unknown. The results shed light on this previously unknown role and demonstrate that science park management is able to facilitate networking among park firms, but apparently unable to (directly) stimulate the innovation process. This was unexpected as previous research show that recurring social interactions should be beneficial in trust building and result in knowledge transfer and subsequent enhanced innovation (Boschma, 2005). The findings suggest that tenant firms perceive a managed science park as beneficial and in particular which activities contribute to social interaction. Developing ties with other firms is associated with the science park management itself, but also community building, providing access to regional and international networks and the creation of an entrepreneurial climate.

In contrast, 'selection criteria for new firms' imposed by science park management is hardly chosen and therefore not related to any of the perceived benefits. These associated managerial activities are somewhat interconnected with a large focus on bringing the right people together, which might suggest that a dedicated 'top-down' managerial entity is more fitting to keep an overview on the park and its community. In contrast, a 'bottom-up' approach with a collection of firms might be less optimal as firms must distribute their time among their core business and park managerial activities. Compared to early science parks, these locations have evolved and require more than just park management (Westhead and Batstone, 1999). Furthermore, Albahari et al. (2018) found that science park management team size is positively related to firm's performance, although this relation is not explained by provided internationalisation or business support services. The study includes far more attributes than the previous authors and the survey show that a larger range of managerial activities are beneficial for tenant firms. This suggests that science park management team size is indeed advantageous for taking care of all those activities and could lead to increased firm performance.

5.6. Conclusion and limitations

The ex-post evaluation of science park performance is a common approach used in studies to evaluate actual firm performance. The significance of this study is to provide insights in perceived benefits for new science park development and management of current science parks. Moreover, it is an investigation of which traditional science park performance indicators are important within the perception of science park tenant firms. The demand-driven approach from the perspective of the science park tenant firm is a relatively underexplored research avenue (Albahari et al., 2019; Lecluyse et al., 2019). The findings provide insight in science park configuration and the role of the science park within innovation policy from the perspective of the tenant firm (i.e., demand-side).

The empirical evidence is in line with the early work of Westhead and Batstone (1999), but is expanded by exploring the perceived benefits of tenant firms. Instead of evaluating the general importance of each aspect separately, the relative importance of each attribute for each benefit is evaluated. Moreover, compared to the case study approach, which yields a detailed exploration of science park management activities (Ratinho and Henriques, 2010), the current study adds an investigation on how these activities are linked to major tenant benefits. Albahari et al. (2018) found no effect on the impact of the presence of internationalisation and business support services on tenants' performance. This study expands the number of considered services by analysing a larger number of attributes that science park management can offer that lead to certain perceived benefits. The current results indicate that tenants acknowledge the value of science park management and its activities and that this is related to networking within and outside the park, attracting funding and providing access to knowledge. With regard to the relation between co-location and knowledge transfer, the results demonstrate that tenants do not see this relationship directly through the use of the science park facilities.

The positive correlation between the attributes 'proximity to university' and 'science park management' with 'access to new knowledge' indicates that synergies among science park attributes exist that are associated to economic, innovation and networking benefits (i.e., 'attracting human talent', 'developing ties with other firms', 'increased sales' and 'new product/services'). The presence of synergies among these science park attributes and additional links with perceived benefits suggests that additional research is required to further explore the impact of science parks on their tenant firms. Future evaluative research should therefore expand on measures to capture science park impact. Comparing only on-park with off-park counterparts might not be sufficient to prove the policy effectiveness of science parks. The study does show that tenants strongly associate the science park management with developing ties with other firms. As repeated interactions are supposed to enhance mutual learning (Boschma, 2005), science park management teams are likely to have a positive indirect impact on innovation.

Furthermore, traditional science park performance indicators, such as 'increased sales' and 'new products/services' often used in evaluation research were also important within the perception of tenant firms. As the recent focus of science park evaluation research has shifted towards the investigation of innovation performance (e.g., Vásquez-Urriago et al. 2016; Ubeda et al. 2019), some indicators are represented less within current science park research. The benefits that were important to tenant firms revealed that some of these underemphasised indicators might deserve some more attention in the future. The perceived benefits: 'attracting human talent', 'developing ties with other firms' and 'attracting funding growth/innovation' have gained little research attention in recent years, while 'cost saving' was never operationalised within science park evaluation research as a performance indicator. Therefore, future evaluation research should delve into these 'forgotten' performance indicators and attempt to measure 'cost saving' as these benefits were also perceived to be important by tenant firms. In addition, current research focuses heavily on the front matter of innovation output (i.e., patents/licenses), while within the perception of science park tenant firms, products/services are relatively more important.

For both policy-makers and science park management this study provides some important implications. For policy-makers the location-based characteristics of science parks seem to fulfil a wide range of benefits according to tenant firms. It is therefore crucial for policy-makers and property developers to align future science parks with the needs of target groups to develop science park locations near universities, research institutes and similar firms. In addition, one of the distinctive characteristics of a science park compared to a business park is the presence of a dedicated science park management team (e.g., Westhead and Batstone, 1999; Albahari et al., 2018). This study reveals that according to tenant firms the science park management team is especially beneficial in facilitating ties between firms, while additional efforts are needed to connect cognitive and organisationally similar firms to enhance innovative performance. Furthermore, this suggests that for planned knowledge-based area developments like science parks, a 'top-down' approach with a managing entity (i.e., managing the park and its community) is needed and appreciated by tenants for directly stimulating interaction and indirectly knowledge transfer.

In contrast, an entrepreneurial 'bottom-up' approach, where the collective of firms is responsible for these activities is less favourable. Moreover, indirectly a large range of managerial activities are perceived as valuable for tenants to attain economic, innovation and networking benefits. Tenant firms expect that science park management organisations are responsible for the inward and outward socialising, networking and knowledge transfer on science parks. This further underlines the value of the managerial effort on science parks and understanding the tenant needs.

This study is not without its limitations. In order to gain insight in the perceived attribute-benefit links among science park firms through an online interview, the small sample size of 51 firms is inevitable. The sample is relatively small to some empiric evaluative work ranging from hundreds of firms (e.g., Dettwiler et al., 2006; Lamperti et al., 2017) to thousands (e.g., Vásquez-Urriago et al., 2016; Díez-Vial and Fernández-Olmos, 2017). However, it is considerably large compared to case study-based interview studies (e.g., Chan and Lau, 2005; Albahari et al., 2019). Considering the exploratory nature of this research, on the level of associations, meaningful associations are found between attributes and benefits. However, the small sample of firms does not allow for statistical testing of the impact of firm characteristics or the segmentation of tenant types as, previously done by Ng et al. (2019b). Other limitations include considering only science parks in the Netherlands and unobserved science park management characteristics. Therefore, a similar study can be conducted to investigate possible country specific differences. Furthermore, only university-ownership is used as a descriptive variable for the science parks in the sample. Future research can consider the influence of the experience of the science park management (Fukugawa, 2013) and the science park governance model. Previous research has shown that science park management characteristics have possible merits for its tenants (Kharabsheh, 2012; Albahari et al., 2017).

Several research lines can be considered within perceptual measures of science parks. First, the next step would be to acquire insights in differences in needs between various types of firms, which would require far larger sample sizes to account for differences among firm segments. The results demonstrate that science park firms are active in a wide range of business development phases, whereas the needs might be heterogeneous (Ferguson and Olofsson, 2004; Ng et al. 2019b). Secondly, although the free response format for science park attributes is used, perceived benefits are retrieved through a priori defined lists. Within the open answers for benefits, respondents mentioned amongst others: 'inspiration', 'employee satisfaction', 'demand estimation' and 'no growing pains'. This suggests additional research is needed on other benefits outside of the commonly used firm performance indicators. Lastly, the results show that the chosen attributes and benefits suffice in distinguishing means and ends on science park, but more detailed endeavours are encouraged (i.e., on facility/service level, proximity type or science park management characteristics). Within the research on perceptual measures of science parks, this research has revealed which facets of the science parks could be means to attain specific benefits according to tenants in general.

CHAPTER SIX

Stated Location Choice of Technology-based Firms

This chapter is based on:

Ng, W. K. B., Appel - Meulenbroek, H. A. J. A., Cloodt, M. M. A. H., Arentze, T. A. (Submitted). Analysing Science Park Location Choice: A Stated Choice Experiment among Technology-Based Firms.

6.1. Introduction

Science parks are the result of supply-driven policy that aims to facilitate networking and economic activity among technology-based firms, university and research institutes (Edler and Georghiou, 2007). Science parks might offer a bridging function between academic knowledge and industry (Lamperti et al., 2017). In literature the general term science park embodies a large range of similar objects, such as hi-tech parks, science and technology parks, research parks and technopoles. The interchangeability of these terms in past empiric studies has been criticised (Hanson et al., 2005) and limited attention is given to these areas themselves (Ramírez-Alesón and Fernández-Olmos, 2018). The existing science park literature focuses largely on proving the impact of presence on a science park on tenant firm performance and therefore policy effectiveness (Albahari et al., 2010). In this context science park evaluation studies include explanatory variables, such as characteristics of technology-based firms, while attention is not always given to characteristics of the science parks themselves. Evidence was found that a larger science park management team positively affects firm performance, while this effect is not explained necessarily by the services provided to tenants (Albahari et al., 2018). Furthermore, Ng et al. (2019a) distinguished science park types in Europe on the presence of knowledge-intensive organisations, facilities offered, size and ownership characteristics, and showed that many different configurations exist. This makes comparing or evaluating science parks challenging (Etzkowitz and Zhou, 2017).

From an economic perspective, the supply of real estate is inelastic as a result of the long lifespan of buildings, while the demand for adequate space and quality can be more dynamic and related to the needs of users (Geltner and Miller, 2001). Within the science park context, the supply-side consists of the design-related attributes like geographical location, buildings, facilities and services with the latter being the most flexible. The demand-side consists of the needs of technology-based firms and other resident organisations towards that what a science park can supply to them. The mismatch between the science park's supply-side and the firm's demand has been acknowledged by science park managers as troublesome (Albahari et al., 2019). A mismatch might negatively affect tenant performance as they do not have access to adequate facilities and services that could support their R&D and business activities.

From the perspective of the science park, new firms might reconsider other locations that more clearly match their needs. For policy-makers, these consequences could jeopardise their objective of supporting the development of technology-based firms (Good et al., 2019).

The demand-side of science parks is often studied through the perceived benefits of its users. Van Dierdonck et al. (1991) inquired Dutch and Belgian science park tenant firms on their most important motivations to move to their science parks. Half of their respondents did not mention the potential link with the local university as the most important motivation, while other aspects include accessibility, image of the site and financial incentives. Moreover, Westhead and Batstone (1999) focused on the perceived benefits of tenant firms regarding managed and non-managed science parks. Link and Scott (2003) studied which benefits academic administrators perceive of science parks for their respective universities. Ferguson and Olofsson (2004) compared growth rates of new technology-based firms on science parks and not located science parks in relation to their perceived location benefits. From the facility management lens, Dettwiler et al. (2006) compared perceived location benefits between on- and off-park technology-based firms. Albahari et al. (2019) explored how facilities and services created value for tenant firms through case studies in Sweden. Lastly, Ng et al. (2019b) studied the associations science park tenant firms make between facilities and services and perceived benefits. However, still little is known about the preferences tenant firms have regarding science park locations and how much value they attach to certain attributes of the parks.

Therefore, this study aims to highlight the demand-side of science parks and in particular the preferences of technology-based firms with regard to the supply-side, i.e., science park attributes and which trade-offs are made by firms when choosing where to locate their firms. Compared to existing evaluative science park research the current study focuses on the relevant science park attributes and levels, which might include non-existing science park configurations, and insights will therefore be useful for policy-makers. As science parks are often (partially) financed by governments in order to reach policy goals, it is vital that these objects are configured effectively (Monck and Peters, 2009).

Consequently, the main research question is: "*Which trade-offs do technology-based firms make regarding design-related science park attributes and what are they willing to pay for these attributes?*" In this research the design-related science park attributes are amongst others the physical and non-physical attributes of the science park location, facilities and services. To answer this question this study adopts a stated preference approach, also known as stated choice experiment, to model the preferences of technology-based firms. The utility firms that assign to the design-related attributes can be expressed in their willingness to pay for these attributes. Consequently, organisational characteristics (i.e., covariates) are considered that might impact firms' preferences and their willingness to pay. The stated choice approach is commonly used in travel-behaviour research and other areas of consumer research and allows, in this case, to measure the preferences of firms regarding hypothetical science park configurations controlled by the researcher (Hensher et al., 2015). This enables the exploration and experimentation of a wide range of types and serves as an advantage compared to evaluating existing science parks as their configurations are as-is. To the author's knowledge, the stated choice method has not been used within the context of science park location choice.

In this study, the focus lies on preferences among a heterogeneous group of decision-makers from technology-based firms located on different locations, within various business development phases, technology domains and firm ages in the Netherlands.

This chapter is structured as follows: first the literature review is discussed on the location choice preferences of technology-based firms, which will serve as input for the design of the stated choice experiment. The methods, which consist of the sampling procedure, the operationalisation of the location choice preferences, design of the choice experiment and discrete choice modelling are found in section 6.3. Next, the results including the sample description and choice modelling results are discussed. Lastly, in section 6.5 the main conclusions of this study, limitations and future research are found.

6.2. Literature review – technology-based firm's location choice

In this section the main drivers of the location choice of technology-based firms are discussed, which will form the input for the design of the stated choice experiment. First, the general location choice considerations of firms are discussed. Then in the following sub sections, the specific aspects that affect the location choice of technology-based firms are discussed, which are the proximity of the university, firm diversity within the area and the (science park) facilities and services provided.

6.2.1. Firm's location choice

In understanding location choice of firms, it is vital to consider the rationality of maximising profits or utility through the choices they make (Pusterla and Resmini, 2007). The resulting uneven distribution of industrial activity among geographical locations is explained through agglomeration economies, where firms experience proximity benefits among stakeholders (Fujita et al., 1999). Firms are largely concentrated when transportation of raw materials or products would otherwise lead to high costs. This basic economic principle would imply that firms that indulge in technology-based activities do not necessarily have to co-locate, as the assets of these firms are mainly intellectual property, i.e., ideas and patents and other mechanisms would dictate the transfer of these assets (Stuart and Sorenson, 2003). However, examples in the US with high concentration of technology-based firms within Silicon Valley and Boston's Route 128 and in Europe the cases of Cambridge in UK and Heidelberg in Germany, show that knowledge-intensive activity does have a spatial dimension too (Saxenian, 1996; Cooke, 2001). Existing literature has suggested that metropolitan areas or cities have attracted economic activity for various reasons (Florida, 2014). Metropolitan areas allow firms to reduce transportation costs through the proximity to markets and agglomeration benefits. Furthermore, lower transportation costs and higher economic activity lead to a high concentration of firms as these costs are related to distance (Krugman, 1991).

For the firms' employees these locations could also be attractive for the proximity of goods and services, i.e., urban externalities (Verhoef and Nijkamp, 2003). Baptista and Mendonça (2010) found that knowledge-intensive start-ups prefer to be located further away from large cities in order to start their business within the local market.

Boschma and Frenken (2009) argued that although many innovation networks are geographically concentrated due to transportation costs, the social proximity among actors cannot be ignored. The uneven spatial distribution of entrepreneurial activity is likely related to the capabilities of firms, availability of opportunities and human capital (Baptista and Mendonça, 2010). It is argued that the geographical proximity towards multiple knowledge sources (i.e., universities, research institutions and firms) enhances the ease of creating and transferring tacit knowledge (Ponds et al., 2007). Feldman (1999) posited that localised knowledge spillovers contribute to innovation and that these spillovers are represented in patent citations, people and R&D. Furthermore, new technology-based firms located on science parks have significantly more R&D output than off-park counterparts through more efficiently investing in innovations as a result of public policies, location benefits and agglomeration effects (Yang et al., 2009).

6.2.2. Proximity to university

The geographical proximity between a university and firms is likely to reduce search costs for valuable knowledge and to improve chance encounters between individuals that enable innovative opportunities (Feldman, 1999). Moreover, universities and public research organisations could serve as anchor organisations that create value for other closely located organisations (Clarysse et al., 2014). An anchor organisation is highly active in R&D and creates knowledge externalities through proximity (Agrawal and Cockburn, 2003). Geographical proximity has been suggested by Ponds et al. (2007) to be a means to overcome institutional distance between firms and universities for scientific collaboration. Both Ferguson and Olofsson (2004) and Dettwiler et al. (2006) found that new technology-based firms most valued the proximity to university among different perceived benefits. Firms that have previous collaborative agreements with universities are more able to strengthen their absorptive capacity and enhancing their innovation performance (Díez-Vial and Fernández-Olmos, 2015). However, Woerter (2012) argued that small firms will likely have lower absorptive capacity than larger firms. Therefore, smaller firms will be more eager to collaborate with universities and a high technology proximity between these firms and university could contribute to knowledge transfer. Similarly, Albahari et al. (2017) posited that firms benefit from university knowledge, but more effort is required for commercialising this knowledge. Moreover, they did not find significant more collaborations between firms and universities on Spanish science parks. Furthermore, Link and Scott (2006) revealed that employee growth decreases on science parks when geographical distance of universities increases, which is largely related to the limited means for knowledge transfer. The current study focuses on the Netherlands, where four technological universities and eight university medical centres are located. On a majority of these locations, science parks are present on-site (see Table 40).

Table 40 Dutch science parks of interest, universities and university medical centres

Science parks	Acronym	zip code	Province	Main focus
Amsterdam Science Park	ASP	1098	Noord-Holland	HT & BT
Brightlands Chemelot Campus	BCC	6167	Limburg	HT & BT
Campus Groningen	CG	9747	Groningen	BT
Delft University of Technology	TUD	2628	Zuid-Holland	HT & BT
Eindhoven University of Technology	TUE	5600	Noord-Brabant	HT & BT
High Tech Campus Eindhoven	HTC	5656	Noord-Brabant	HT & BT
Kennispark Twente	KPT	7522	Overijssel	HT & BT
Leiden Bio Science Park	LBSP	2333	Zuid-Holland	BT
Utrecht Science Park	USP	3584	Utrecht	BT
Wageningen Campus	WC	6708	Gelderland	HT & BT
Technical universities	**Acronym**	**zip code**	**Province**	
Delft University of Technology	TUD	2628	Zuid-Holland	
Eindhoven University of Technology	TUE	5600	Noord-Brabant	
University of Twente	UT	7522	Overijssel	
Wageningen University	WU	6708	Gelderland	
University Medical Centres	**Acronym**	**zip code**	**Province**	
Academic Medical centre UVA	AMCUVA	1105	Noord-Holland	
Erasmus University Medical Centre Rotterdam	EUMCR	3015	Zuid-Holland	
Leiden University Medical Centre	LUMC	2333	Zuid-Holland	
Maastricht University Medical Centre	MUMC	6229	Limburg	
Radboud University Medical Centre Nijmegen	RUNMC	6525	Gelderland	
University Medical Centre Groningen	UMCG	9713	Groningen	
University Medical Centre Utrecht	UMCU	3584	Utrecht	
VU University Medical Centre	VUMC	1081	Noord-Holland	

Note. HT = High-tech, BT = Biotechnology

6.2.3. Firm Diversity

The effects of (dis)similarities among activities and technology domains of firms have been widely researched. Firms active within a strict technology domain are likely to achieve short-term success within their own area of expertise. In contrast, firms active in different technology domains might explore newer domains and gain success in the long-term (Rosenkopf and Nerkar, 2001). In the science park context, firms are more likely to collaborate with each other through a wider range of activities (Vásquez-Urriago et al., 2016). New technology-based firms who can complement each other with joint collaboration and exporting activities are more likely to have higher innovation performance, whereby the disadvantages of knowledge spillovers are diminished (Ramírez-Alesón and Fernández-Olmos, 2018). Shearmur and Doloreux (2000) argued that the sectoral mix on science parks can be explained by two reasons; as a strategy to contribute to synergy among firms or as a real estate decision to avoid vacant premises. Research in Italy on 'specialised' science parks (i.e., hosting many firms active in a few sectors) and 'general' science parks (i.e., many firms active in different sectors) shows that the former science parks have a positive effect on firm investments, while the latter are more able to improve sales performance of tenant firms (Liberati et al., 2016).

Firms active in technology sectors, such as biotechnology, are more likely to co-locate with other similar firms as a means to get access to the specialised local educated workforce, experience and specific materials (Stuart and Sorenson, 2003). Regions that co-locate a high number of firms with the same specialisation are exposed to less risk to fail through the proximity of specific suppliers, markets, infrastructure, networks, human talent and potential knowledge spillovers (Renski, 2011). Also, Link and Scott (2006) showed that science parks focused only on information technologies grow faster than parks focused only on biotechnology or multiple different sectors. Koçak and Can (2014) found some evidence supporting that more knowledge sharing and client ties are found at science parks with more tenant firms in the same industrial activity group. The close proximity of similar firms active in innovation could lead to both competition and collaboration (Lamperti et al., 2017).

In contrast, a wide range of sectors could lead to technological breakthroughs, as innovation is often a product of the technological recombination of inventions from various technologies, components or processes from multiple firms (Adner and Kapoor, 2010). A diversity of firms complemented with non-profit knowledge institutions allows for a diverse flow of information and different measures for success (Powell et al., 2010). It is this diversity that allows each individual actor to be more able to recognise new opportunities within their own specialisation, while the collection of organisations will be able to retrieve knowledge from different domains (Van Der Borgh et al., 2012).

6.2.4. Science park facilities and services

Science parks provide firms, higher educational institutions and research institutes both configurative and process-related amenities, which are respectively the physical infrastructure (facilities) and the services that contribute to their organisational goals (Albahari et al., 2019). Various types of facilities are provided on the science park area, such as specialised R&D facilities (e.g., laboratories, cleanrooms, piloting rooms), business facilities (e.g., offices, meeting rooms, conference rooms, canteens, restaurants, shops) and leisure facilities (e.g., cinema, sport facilities) (Ng et al., 2019a). Business specific services are for example administrative, marketing and managerial support, venture capital access, training programs, while other services include social networking events, park management, cleaning and maintenance (Ratinho and Henrique, 2010). These facilities and services are provided for private use or shared usage among tenants in which the latter allows for economies of scale and collaborative purposes (Chan and Lau, 2005; Brinkø et al., 2014). Dettwiler et al. (2006) argued that new technology-based firms on science parks are more able to develop their networks through their contractual agreements with the science park and availability of facilities. Similarly, Schiavone et al. (2014) found that science park tenant firms have access to more opportunities and resources within the science park environment which benefits their innovation performance. For new technology-based firms the access of facilities and services within their initial start is beneficial, but when these firms mature they are less likely to share knowledge as competition rises (McAdam and McAdam, 2008). Specifically, for these smaller and younger firms the networking events and training are of interest as they lack the financial and organisational capacity to do so on their own (Chan and Lau, 2005; Löfsten and Lindelöf, 2005). Networking events enable the interaction between different co-located actors and repeated interactions between these actors is expected to contribute to knowledge sharing (Inomata et al., 2016). Science park tenant firms associate both training programs and business networking events with knowledge sharing and collaboration and to be closer to the university and new clients, while networking events also serve the purpose of meeting other firms (Ng et al., 2019b). Soetanto and Jack (2013) posited that within their networking activities new technology-based firms are more interested in seeking intangible resources (i.e., combine technical or market-related knowledge) than tangible resources (i.e., combine assets or use of R&D facilities and equipment). This suggests that these younger firms are less likely to collaborate in a physical sense through shared use of facilities and co-location might be less important for them. However, the transfer of difficult to codify knowledge is eased through repeated face-to-face interactions (Storper and Venables, 2004).

To summarise, the first main driver of the technology-based firm's location choice are location-specific factors. These factors are related to the means of transportation and the urban context of the firm's location, which is related to agglomeration benefits and access to markets. The second driver is proximity of university, which serves as a potential source for knowledge, collaborative opportunities and human talent. Furthermore, the firm diversity of a location can be focused on firms active in similar or in a wide range of technology sectors with different impacts on collaboration opportunities, knowledge production and valorisation.

Lastly, the provision of facilities and services provided by science parks involve specific R&D facilities and equipment, but also more general business support facilities/services and leisure facilities, which allow tenant firms to focus on their core business activities, to network and share knowledge. These four main drivers will be further operationalised in the next section in order to incorporate them in the experimental design.

6.3. Sampling and methods

The needs or perceptions of technology-based firms are a relatively underexplored research avenue. The perceived benefits of firms in relation to the science park location has often been studied through ranking or Likert measures (e.g., Van Dierdonck et al., 1991; Westhead and Batstone, 1999; Ferguson and Olofsson, 2004). These studies show the importance of various science park attributes separately, but the relative importance or trade-off that technology-based firms make among typical attributes remains unknown. The current approach attempts to determine the firms' preferences for specific attribute levels and the overall perceived importance of all considered attributes.

To gain insight in the design-related preferences of technology-based firms in relation to science parks, a stated choice experiment is designed. The stated choice framework is an experimental approach that allows for the estimation of the utility of attributes within the trade-offs that firms make (Hensher et al., 2015). In this section the sampling of decision-makers is briefly discussed, followed by an operationalisation of the main location drivers derived from literature for the experimental design. Then the covariates (i.e., organisational characteristics) are operationalised in order to study possible preference differences among firms. Lastly, the analysis procedure of discrete choice modelling is discussed.

6.3.1. Sampling of technology-based firms

The stated choice experiment is administered by an online survey among a sample of firms, in order to gain insight in design-related preferences of technology-based firms. According to Sanni et al. (2009) preferences of existing science park tenant firms are somewhat biased due to their choice to select the science park location in the first place, which implies they have specific preferences. This issue could be reduced with a control group of off-park technology-based firms that are not subjected to influences from the science park location and have not chosen a science park location in the first place (Siegel et al., 2003a; Vásquez-Urriago et al., 2016). The current study on decision-making of both on- and off-park firms uncovers a part of the factors related to their location preferences. The desired respondents are C-level representative decision-makers of technology-based firms: CEO, CTO, CFO, COO, etc. A disadvantage of targeting these respondents is that these representatives often have tight time schedules as a result of daily business operations, which could limit the number of responses (Mintzberg, 1973). However, executive-level employees are considered subject matter experts and a reliable source of information of organisational processes (Norburn, 1989) and, therefore, can also participate as respondent. Science park firms are contacted that are located on the ten largest science parks in the Netherlands. The majority of science parks are focused on high-tech and/or biotechnology sectors and located within the same area or within the same city of a technical university or university medical centre (see Table 41).

High-tech focused science parks include firms active in a wide variety of sectors such as: aerospace, computer science, electronics, new materials, photonics and robotics. For technical universities, high-tech science parks are located on-site or not in the vicinity at all; with an exception of HTC. For university medical centres, some biotechnology science parks are located on-site, while others are located within a distance of 50 kilometres.

Table 41 Distance in kilometres between science parks and institutions in the Netherlands

Technical universities & high-tech focus science parks					
Distance in km	TUD	TUE	UT	WU	Average
ASP	65	122	155	76	105
BCC	237	252	143	145	194
HTC	130	7	187	89	103
KPT	203	170	0	114	122
TUD	0	130	203	104	109
TUE	130	0	170	79	95
WC	104	79	114	0	74
Average	124	109	139	87	

University Medical Centres & biotechnology focus science parks									
Distance in km	AMCUVA	EUMCR	LUMC	MUMC	RUNMC	UMCG	UMCU	VUMC	Average
ASP	10	78	49	213	120	178	50	193	111
BCC	184	182	208	21	115	317	160	39	153
CG	203	247	221	336	196	0	188	183	197
HTC	118	114	139	90	77	261	93	126	129
KPT	155	198	200	247	112	147	136	163	172
LBSP	48	39	0	225	134	220	64	163	112
TUD	64	14	26	216	143	237	72	56	109
TUE	114	116	136	89	66	251	90	122	124
USP	37	66	63	181	90	187	0	39	83
WC	74	98	98	165	33	188	44	56	95
	101	115	114	178	109	199	90	114	

All parks provide facilities and services for shared or private use for technology-based firms, research institutes and service providers. For the off-park firms, zip codes not similar to those of science parks are considered. Through online desk research a list is established with 482 off-park technology-based firms with publicly available e-mail addresses to be contacted to partake in this study.

Both on-park and off-park technology-based firms are defined by their technological sectoral focus and business activities related to creating, designing or developing new products, services, systems or processes. The survey was hosted online in the period between December 2018 and April 2019 with reminders sent to firms in January and March 2019.

6.3.2. Design of attributes and experiment

The four main drivers for the technology-based firm's location derived from literature will serve as the input for the operationalisation of the attributes used in the stated choice experiment. In this study the hypothetical alternatives are area developments with typical science park attributes to be evaluated by respondents. For the facilities and events attributes, these are present within the immediate location and therefore within walking distance. The configuration of the hypothetical locations consists of seven attributes with each varying among three levels (see Table 42).

Table 42 Attributes and levels science park choice experiment

Main driver	Attributes	Attribute levels
Location	Location	Level 1: station location - within 0.8 km from central train station and more than 2 km from nearest highway entrance.
		Level 2: suburban location - within 0.8 km from central train station and within 2 km from nearest highway entrance.
		Level 3: highway location - more than 2 km from central train station and within 0.8 km from nearest highway entrance.
Proximity of university	University	Level 1: in the same area
		Level 2: not in the area, but in the same city
		Level 3: in a different city
Firm diversity	Firm diversity	Level 1: all technology domains are present
		Level 2: limited number of technology domains including yours
		Level 3: same technology domain as yours
Science park facilities and services	R&D facilities	Level 1: for shared use among multiple organisations
		Level 2: for private use for your organisation only
		Level 3: none in the area
	Shared facilities	Level 1: shared business and leisure facilities in the area
		Level 2: shared business facilities in the area
		Level 3: none in the area
	Events	Level 1: both networking events and training events are held
		Level 2: networking events are held
		Level 3: none are held
Willingness to pay	Cost	Level 1: plus 10% on total current cost of use
		Level 2: same as the total current cost of use
		Level 3: minus 10% on total current cost of use

6.3.2.1. Design of attributes

The location-specific factors, which involve modes of transportation and accessibility is adopted from De Bok and Van Oort (2011). The distance values (0.8 and 2 km) related to 'station location', 'suburban location' and 'highway location' reflect the densely populated polycentric character of the Netherlands (Burger and Meijers, 2012). The Dutch firm location policy is largely focused on the accessibility on three dimensions: the proximity to the central business district, to railway stations and to highways (Schwanen et al., 2004).

Proximity of university that is relevant for the decision-maker is defined by the geographical distance between the area and the university. The discrete levels are in line with the existing situation in the Netherlands. The distance between the ten science parks of interest and the technical universities and university medical centres are listed in Table 41. The majority of high-tech focused science parks are located in the same area as a technical university or not in the vicinity at all. Some biotechnology-focused science parks are located in the same area as a university medical centre or in a distance of approximately 50 km (i.e., in a different city).

Firm diversity refers to the (dis)similarity of technology domains, i.e., type of technology sectors, activities and R&D output. This attribute is derived from Liberati et al. (2016) and defined with the levels: 1) all technology domains are present in the area, 2) firms are focused on a limited number of technology domains including that of the decision-maker and 3) firms are focused on the same technology domain as the decision-maker.

The provision of facilities and services are captured through the attributes R&D facilities, shared facilities (i.e., business support and leisure facilities) and events that the science park location can provide. Business support facilities are for example conference rooms, meeting rooms, dining facilities, while leisure facilities are sport facilities, cinema etc. Events held in the area are comprised of networking events and training events held on location. These two types of services are distinguished as, on one hand, networking events aid firms in seeking new opportunities (Löfsten and Lindelöf, 2005) and, on the other, training programs aid firms in their business activities (Albahari et al., 2019).

Finally, the cost attribute that enables the estimation of the willingness to pay for the other attributes (levels) are the location use expenses for firms (i.e., rent). This is an important factor that impacts the overall utility of a location. Specifically, for new technology-based firms who need more development time, the possible rental subsidies from science parks are important, as normal rent prices on science parks are generally higher than market prices (Chan and Lau, 2005). Dettwiler et al. (2006) found that off-park new technology-based firms are more concerned with rental cost than on-park, which the authors attributed to different contractual agreements and facility solutions on science parks. The costs of use include the costs of acquiring or leasing the facilities, operational costs (i.e., maintenance and energy expenses) and the costs of additional services. Saving costs from infrastructure allows firms to allocate resources to their innovation efforts (Durão et al., 2005). Within the science park context renting facilities is arguably the most common arrangement for technology-based firms (Chan and Lau, 2005; Ratinho and Henriques, 2006; Squicciarini, 2008).

In general, more central areas are more expensive, while Audretsch et al. (2005) found that for firms the cost of being closely located to universities surpasses the benefits of knowledge spillovers.

In the current study, the cost parameter is defined with three levels which refers to decision-makers existing total cost of use. This parameter is defined at the levels: 1) plus 10% on total current cost of use, 2) same as the total current cost of use, and 3) minus 10% on total current cost of use. Inquiring respondents for their actual total current cost of use was not considered as agreements are individually made and are likely to be influenced by many unobservable factors. Moreover, rental prices of physically similar spaces may differ significantly due to location factors (Geltner and Miller, 2001).

6.3.2.2. Design of the experiment

The seven attributes are the characteristics that define the hypothetical science park alternatives within the choice tasks presented to decision-makers of technology-based firms. The explicit question in each choice task is: *"suppose your organisation or branch office should relocate and you could choose between the following two hypothetical location alternatives or choose to not relocate. The three alternatives are identical for all characteristics that are not explicitly mentioned"*. Each respondent is presented with nine choice tasks each with two hypothetical alternatives and an opt-out option. The use of an opt-out option is suggested to limit the hypothetical bias to some degree and result in more realistic preferences (Ladenburg and Olsen, 2014) and could link the alternatives closer to the respondent's actual situation (Hensher et al., 2015). In the current study, the opt-out option is for firms equal to preferring their current situation. The inclusion of an opt-out option does not increase the required number of choice sets as it is static among all tasks.

In the science park context, an unlabelled choice experiment would be more appropriate as respondents may not fully understand the concept or know its interchangeable names, i.e., science, technology or research park, campus (Hansson et al., 2005). Furthermore, the labels of these park types offer no meaningful associations for the decision-makers compared to, for example, choice experiments regarding transport choice (e.g., bus vs car). In this way, the choice data collected is solely based on the attributes of the unnamed alternatives and leads to design principles also suitable for broader knowledge-based and business-oriented real estate developments. In addition, the use of unlabelled alternatives decreases the required number of choice sets significantly. The number of possible design profiles for unlabelled choice alternatives is L^H with L as the number of attribute levels and H as the number of attributes (Hensher et al., 2015). It is crucial to limit the number of design profiles in order to reduce cognitive burden of respondents. In an unlabelled experiment with seven attributes with each having three levels, the number of all possible design profiles equals $3^7 = 2{,}187$.

As this number is far too large to present to respondents this should be reduced significantly. Therefore, an orthogonal fractional design is used that consists of a smaller fraction that still allows for the estimation of the utilities for all attributes. The smallest design based on seven attributes each with three levels consists of 27 profiles (Hahn and Shapiro, 1966). This design allows for estimation of all main effects as well as the estimation of interaction effects (i.e., multiplication) between the first and second, and second and third attribute ('location', 'university' and 'firm diversity' respectively). Within each choice task it is crucial to pair two different profiles as two identical profiles would limit the information obtained from the choice. Furthermore, choice sets with different unique pairs of profiles are useful to reduce order effects (Hensher et al., 2015). Therefore, each profile in the fractional design is paired with another profile. Profile 1 to 9 are shown to respondent 1 within the alternative 1 slot and each of those profiles are paired with one of the other 26 profiles in the alternative 2 slot, profiles 10 to 18 for respondent 2, etc. To ensure a somewhat random order, the fractional design profiles are paired eleven times whilst making sure that all profile pairs are unique across all versions.

6.3.3. Operationalisation of covariates

In order to investigate possible differences in preferences between technology-based firms, a number of covariates are included. These covariates are mainly organisational characteristics and characteristics of the respondent's current location (see Table 43). The reason to include these covariates in the online survey is to find possible differences in the base preference for the opt-out option (i.e., current situation) and differences in attribute evaluation among decision-makers. In order to avoid multicollinearity issues the Pearson's correlation test is used to seek potential redundant covariates. Covariates with correlations that exceed a certain threshold can be omitted from the further analysis of the choice data (variables with $r \leq 0.5$ are suitable). In the survey the covariates are inquired before the choice experiment as it allows the respondent to familiarise with a majority of the attributes within the stated choice experiment.

The first covariate is to check if the responding firm's headquarter is currently located on a science park in the Netherlands. Larger and more mature firms are likely to have multiple business locations and therefore firm age and size are also included. In terms of technological focus and activity, the covariates 'sectors' and 'new product development activities' are used. In addition to technology-related sectors, science parks can provide a base for operations for other service firms (i.e., consultancy and servicing companies). The last group of covariates consists of the access to different facilities and services. Within their current headquarter location, firms are asked if they have access to the various facilities in their current area. For the access to training events and networking events a Likert scale is used to measure the frequency of relevant events held for these firms in their current location.

Table 43 Covariates with levels choice experiment

Covariates	Levels	Source
Science park firm (binary)	Firm located on a science park	e.g., Dettwiler et al. (2006), Ubeda et al. (2019)
	Firm not located on a science park	
Location type (binary)	Firm located in a station or suburban location	De Bok and Van Oort (2011)
	Firm located in a highway or rural location	
Firm age (continuous)	Establishment in years	
Firm size (categorical)	Less than 10 employees	OECD (2015b)
	Between less than 10 – 49 employees	
	Between 50 and 249 employees	
	Above 250 employees	
Sectors	Aerospace and transportation	WAINOVA (2009), Sanz and Monasterio (2012)
(18 binary)	Agriculture, forestry, earth and metrology services	
	Bio/medtech, life sciences and pharmaceuticals	
	Chemistry and new materials	
	Civil and construction engineering	
	Computer and software engineering	
	Electronics – nano electronics	
	Energy and environmental technology	
	Food sciences	
	Industrial manufacturing	
	Internet technologies	
	Mechatronics	
	Micro- and nanotechnology	
	Optics	
	Robotics and automation	
	Sensors and instrumentation	
	Service company	
	Other sectors (own input)	

Table 43 (continued)

Covariates	Levels	Source
New product development activities (four binary variables)	Concept development (addressing needs of customers through concepts). Design and Engineer (creating a profitable product, product or process that meets the needs of customers). Prototype development & testing (testing and evaluation). Launch (full-scale commercial).	Dahan and Hauser (2002)
Access to facilities (eight binary variables)	Laboratory Clean room Piloting room Meeting room Conference room Dining facility Sport centre Sporting grounds	WAINOVA (2009), Sanz and Monasterio (2012)
Frequency relevant events (Likert scale)	Training events Networking events	Ng et al., 2019b

6.3.4. *Discrete choice modelling*

Through the analysis of choice data of the technology-based firms the part-worth utility for each attribute level can be identified. Respondents convey their stated preference through their choice among two hypothetical location alternatives and to not relocate. The main aim of this method is to fit the choice data within a linear function. In this section the utility function, mixed multinomial logit model and the willingness to pay estimation are discussed.

6.3.4.1. Utility function

The standard utility function for decision-maker n for an alternative i (U_{in}) is the sum of the part-worth utilities (V_{ijn}) of all attributes j and an error component ε (Equation 1). This latter component embodies that what is unobserved within the choice experiment, as not all relevant attributes can realistically be included (Hensher et al., 2015). In the choice experiment, the decision-makers of technology-based firms receive hypothetical relocation options and a choice of not relocating. The reference utility component α_n is included as the utility of not relocating and, hence, represents a base utility U_{0n} (Equation 2). The two utility equations are defined as:

$$U_{in} = \sum_j V_{ijn} + \varepsilon \qquad (1)$$

$$U_{0n} = \alpha_n \qquad (2)$$

The observed part-worth utility V_{ijn} of an attribute is the product of an attribute preference parameter β_j coefficient and attribute level x_{ij}. The β_j parameters are estimated and yield numeric values, while x_{ij} corresponds to the discrete values of attribute levels. Effects coding is used for the attributes. Through effects coding, the reference third base level ('different city' for the university example) is fixed in order to estimate the two other level variables (x_{ij1} and x_{ij2}). It follows that 'same area' is coded as $x_{ij1} = 1$, $x_{ij2} = 0$, 'same city' as $x_{ij1} = 0$, $x_{ij2} = 1$ and 'different city' is codes as $x_{ij1} = -1$, $x_{ij2} = -1$. The part-worth utility $V_{i,universisty3,n}$ of the third reference level is derived from (-1* $\beta_{i,universisty1}$) + (-1* $\beta_{i,universisty2}$), in which the sum of the three levels equals zero. Therefore, the estimated utilities for the two parameters are relative to the referenced base level. This method reflects the fact that the choice of the reference level is arbitrary and only the difference between utilities is meaningful. In the current study, the previously mentioned main effect of the attributes are estimated. In addition, the interaction effects of the product of two attributes and the effects of the covariates on the attribute preferences are also estimated.

For the interaction effects of the attributes, only the multiplication of the first three attributes can be estimated as a result of the chosen design (Hahn and Shapiro, 1966). These interactions are: the attribute levels of 'location' * 'university' and 'university' * 'firm diversity'. A preference parameter ($\delta_{jj'}$) is estimated, which is the added utility of the combination of both attributes in an alternative. Furthermore, preferences among decision-makers are likely to be different as a result of heterogeneity within the group of respondents. De Bok and Van Oort (2011) argued that relocation behaviour is dependent on firm attributes such as firm size, firm age and sector. These covariates (z_{kn} with k as the level of the covariates) enter the standard utility function as interaction effects (δ_{jk}) of attributes (e.g., 'university in the same area' * 'science park firm'). In order to limit redundant covariates, only variables are considered that are not strongly significantly correlated through a Pearson's correlation test to avoid multicollinearity issues (Booth et al., 1994). The inclusion of covariates in the utility function allows for estimating differences in part-worth utilities among decision-makers that have specific firm characteristics.

The part-worth utility (Equation 3) for this study is defined as:

$$V_{ijn} = \sum_j \left(\beta_j * x_{ij} + \sum_{j'} \delta_{ij'} * x_{ij} * x_{ij'} + \sum_k \delta_{jk} * x_{ij} * z_{kn}\right) \quad (3)$$

As this equation indicates, the part-worth utility (V_{ijn}) of an attribute j and alternative i is the sum of three components: the main effects of the attributes (product of attribute preference parameters (β_j) and attribute levels (x_{ij}), the interaction effects with other attributes ($\delta_{jj'}$ * x_{ij} * $x_{ij'}$)), and the interaction effects with the covariates (δ_{jk} * x_{ij} * z_{kn}).

6.3.4.2. Mixed multinomial logit model

As preferences across firms may vary, the mixed multinomial logit model is a suitable extension of the multinomial logit model to estimate the part-worth utilities. The mixed multinomial logit model assumes that all or some of the parameters are random among all decision-makers. Therefore, this method considers the heterogeneity among respondents and the panel data structure by estimating a distribution rather than a point-estimate for each parameter (i.e., multiple observations per respondent) (Hensher et al., 2015). Usually, random parameters are expected to follow a normal distribution and represent the difference in preferences for those attribute levels. To estimate the distribution, a simulated log likelihood method is used where the random preference parameters are drawn from a (normal) distributions. In this method, the use of Halton draws results in lower simulation errors (Train, 1999). For this study, models are estimated using 1,000 Halton draws (Bhat, 2003). For each attribute, only one level can enter the model as a random parameter, for arbitrary reasons this will be the first level. The goodness-of-fit of the estimated mixed multinomial logit model is measured through the ρ^2 and the ρ^2 adjusted with the latter considering the number of parameters. The ρ^2 compares the log likelihood of the null model (alternatives have equal chances of 0.33 within a choice task) and the log likelihood of the estimated model. These measures are similar to the R^2, which expresses the accuracy of the model to predict the data in linear functions. An R^2 of 0.8 for linear functions is considered to be similar to a ρ^2 of 0.4 (Domencich and McFadden, 1975). Therefore, results with ρ^2 between 0.2 and 0.4 suggest a well-fitting model (Louviere et al., 2000).

6.3.4.3. Willingness to pay estimation

The trade-off between attributes can be expressed in monetary terms as the willingness to pay (wtp), which is the ratio of the utility parameters of an attribute level of interest (x_{ij}) and the cost attribute (x_c). This ratio expresses the linear relation between 1 unit change of an attribute and how much the cost attribute has to change to keep the total utility constant. Wtp for attribute *j* is defined as (Hensher et al., 2015):

$$wtp_j = \frac{\Delta x_{ij}}{\Delta x_c} = \frac{\beta_j}{\beta_c} \qquad (4)$$

where β_j and β_c are the marginal utilities for attribute *j* and the cost parameter, respectively.

In order to meaningfully express the willingness to pay for attribute levels, in this case, the estimated values need to be multiplied by 20% (i.e., the range of the cost attribute from minus 10% to plus 10%).

6.4. Results and discussion

6.4.1. Sample characteristics and covariates

In total the survey was completed by 69 respondents with a majority of them active in a decision-making role, which shows that it reached the relevant persons in the organisation (Table 44). 46% of the responding technology-based firms are currently located on a Dutch science park. The majority of the firms is located either in a suburban or highway location. Both the distribution of firm size and firm age suggest that the sample contains more firms in the smaller and younger categories compared to the overall sample. The sampled firms are active in a wide range of technology sectors including services with 'computer and software engineering' and 'bio/medtech' being the two most common sectors. For each firm the total number of selected technology sectors is computed to divide the sample into two groups. 41 firms are active in one or two sector(s) (i.e., 'high technology sectoral focus'). While the remaining 28 firms are active in more than two or zero technology sectors (i.e., 'low technology sectoral focus').

Table 44 Characteristics of 69 technology-based firms in the Netherlands

	n	%		*n*	%
Respondent job position			Sectors[b]		
Chief Officer E, T, O and C[a]	44	64	Computer and software engineering	23	13
Manager – general, production, facility	13	19	Bio/medtech, life sciences and pharmaceuticals	21	12
Others e.g., business developer, specialist	11	16	Service company	17	10
			Industrial manufacturing	15	8
Science park firm	32	46	Internet technologies	13	7
Not-science park firm	37	54	Sensors and instrumentation	12	7
			Chemistry and new materials	11	6
Location type			Aerospace and transportation	10	6
Station location	5	7	Agriculture, forestry, earth and metrology services	10	6
Suburban location	21	30	Energy and environmental technology	7	4
Highway location	34	49	Robotics and automation	7	4
Rural location	9	13	Optics	6	3
			Civil and construction engineering	5	3
Firm size on location in employees			Electronics – nano electronics	5	3
Less than 10	28	41	Other sectors	5	3
Between 10 – 50	28	41	Mechatronics	4	2
Between 50 – 250	9	13	Micro- and nanotechnology	4	2
More than 250	4	6	Food sciences	3	2

Note. [a]Executive, Technical, Operations, Commercial. [b]Respondents were allowed multiple options.

Specifically, firms operating in 'industrial manufacturing', 'sensors', 'agriculture', 'energy' and 'optics' are significantly more active in more than two sectors. The following sectors are found to be significantly more active in two or more sectors compared to the expected probabilities χ^2 (1, n = 69), 'industrial manufacturing' $\chi^2 = 8.53$, $p = 0.003$, 'sensors and instrumentation' $\chi^2 = 11.01$, $p < 0.001$, 'agriculture, forestry, earth and metrology services' $\chi^2 = 8.26$, $p = 0.004$, 'energy and environmental technology' $\chi^2 = 11.41$, $p < 0.001$ and 'optics' $\chi^2 = 4.98$, $p = 0.025$. The vast majority of firms (88%) is active in one of the phases of new technological product development with more firms active in the latter three phases.

Table 44 (continued)

	n	%		*n*	%
Firm age in years (mean: 17.2; SD: 20.2)			Technological activity – New Product Development[b]		
Quartile: 4 or less	17		Engaged in technological R&D	61	88
Quartile: 5 to 9	17		Concept development	36	
Quartile: 10 to 19	18		Design and engineer	42	
Quartile: 20 and older	17		Prototype development & testing	44	
			Launch	43	
			Not engaged in technological R&D	8	12
Access to facilities			Access to services		
Laboratory	48	70	Training events		
Clean room	41	59	Never	26	38%
Piloting room	46	67	Once a month	31	45%
Meeting room	58	84	More than once a month	6	9%
Conference room	38	55	Once a week	2	3%
Dining facility	54	78	More than once a week	4	6%
Sport centre	51	74	Networking events		
Sporting grounds	40	58	Never	27	39%
			Once a month	32	46%
			More than once a month	7	10%
			Once a week	2	3%
			More than once a week	1	1%

Note. [b]Respondents were allowed multiple options.

For the access to facilities and services: meeting rooms, dining facilities, sport centres and laboratories are the most accessible for respondents. The more specialised R&D facilities and larger sport facilities are relatively less often available for the sampled firms. For both training events and networking events, the majority of firms have access to at least one relevant event per month.

6.4.2. Correlation covariates

In order to consider the heterogeneity among the preferences of the decision-makers correlation tests are conducted among the binary covariates. In general, multicollinearity issues might arise when variables have significant and strong correlations (r) (Booth et al., 1994). Considering the small sample size (n = 69) a strict threshold of $r \leq 0.5$ is used to select covariates for further analysis. Strongly correlated covariates are similar and to some degree redundant. The Pearson correlation between whether the firm is already located on a science park ('science park firm') and the access to facilities is above the threshold. Also, the correlations between 'science park firm' and a majority of the variables regarding access to facilities exceed the multicollinearity threshold. The following facility variables are excluded for further analysis: 'laboratories', 'clean rooms', 'piloting, 'conference rooms', 'dining facilities', 'sport centre' and 'sporting grounds'. In a similar way the organisational covariates are also tested for multicollinearity. 'Science park firm' is significantly correlated with 'firm size - less than 10 employees' $r(69) = .354$, $p = .003$ and negatively with 'more than 250 employees' $r(69) = -.267$, $p = .027$. This suggests that science park firms in the sample are relatively small in terms of number of employees compared to the respondents currently not located on a science park. Furthermore, for apparent reasons, some 'Firm size' and 'Firm age' variables are significantly correlated and exceed the multicollinearity threshold (i.e., 'less than 10 employees', 'between 10 – 50 employees' and 'age - 4 or less years' are excluded). The four phases within the new product development process are largely positively correlated. The significant correlations of 'concept development' with 'design and engineer' and 'prototype development & testing' are also too strong in terms of this criterion. In addition, the correlation between 'design and engineer' and 'prototype development & testing' also exceeds the correlation threshold.

To summarise, the remaining covariates are not strongly mutually correlated and are used for further analysis. The considered binary covariates that will be used to test interaction effects on attribute parameters are: 'science park firm', 'meeting rooms', 'training events', 'networking events', 'location', 'firm size - less than 10 employees', 'between 50 and 250 employees', 'more than 250 employees' 'firm age - between 5 to 9 years', 'between 10 to 19 years', '20 years and older', 'high technological sectoral focus', 'prototype development & testing' and 'launch'.

6.4.3. Model estimation results

In total, the respondents are presented 1,863 options and they made 621 choices. The selection frequencies of the 27 design profiles and the opt-out option are found in Table 45. The distribution between design profiles and the opt-out option is respectively 70% and 30% suggesting that for the majority of the choice tasks the design profiles are relevant enough to prefer those over their current situation.

Table 45 Selection alternative designs and existing situation

Frequency chosen		Total	% chosen		Attributes choice experiment						
C	~C	Σ	C%	~C%	Location	University	Firms diversity	R&D facilities	Shared facilities	Events	Cost
36	10	46	78	22	Suburban	Same area	All	Shared	Business	Network	-10%
30	20	50	60	40	Suburban	Same area	Limited	Private	Busi&leis	None	Same
30	17	47	64	36	Station	Same area	Same	Private	Business	None	-10%
26	25	51	51	49	Station	Same city	Limited	Private	Busi&leis	Netw&trai	-10%
22	25	47	47	53	Suburban	Same city	All	Private	None	Netw&trai	Same
21	22	43	49	51	Highway	Same city	All	None	Busi&leis	Network	-10%
21	24	45	47	53	Highway	Same area	Same	Shared	Busi&leis	Network	Same
20	26	46	43	57	Suburban	Other city	Same	Private	Business	Network	Same
20	25	45	44	56	Suburban	Same city	Same	Shared	Busi&leis	None	-10%
19	30	49	39	61	Station	Other city	All	Private	None	Network	-10%
18	28	46	39	61	Station	Same area	All	None	Busi&leis	Netw&trai	Same
17	27	44	39	61	Highway	Other city	All	Shared	Business	Netw&trai	Same
15	28	43	35	65	Highway	Same area	Limited	None	Business	Netw&trai	-10%
14	30	44	32	68	Highway	Same city	Same	Private	Business	Netw&trai	10%
14	35	49	29	71	Station	Same city	All	Shared	Business	None	10%

Table 45 (continued)

Frequency chosen		Total	% chosen		Attributes choice experiment						
C	~C	Σ	C%	~C%	Location	University	Firms diversity	R&D facilities	Shared facilities	Events	Cost
14	33	47	30	70	Station	Same area	Limited	Shared	None	Network	10%
12	32	44	27	73	Highway	Other city	Same	None	None	None	-10%
12	34	46	26	74	Station	Other city	Same	Shared	Busi&leis	Netw&trai	10%
10	36	46	22	78	Suburban	Other city	Limited	Shared	None	Netw&trai	-10%
10	35	45	22	78	Suburban	Same area	Same	None	None	Netw&trai	10%
9	38	47	19	81	Station	Same city	Same	None	None	Network	Same
8	33	41	20	80	Highway	Other city	Limited	Private	Busi&leis	Network	10%
8	36	44	18	82	Highway	Same area	All	Private	None	None	10%
8	40	48	17	83	Station	Other city	Limited	None	Business	None	Same
7	38	45	16	84	Highway	Same city	Limited	Shared	None	None	Same
7	43	50	14	86	Suburban	Other city	All	None	Busi&leis	None	10%
6	38	44	14	86	Highway	Same city	All	None	Busi&leis	Netw	-10%
434	808	1,242									
187	434	621	30	70	Preference for the existing situation						

With the mixed multinomial logit model the final model is estimated and discussed here. In this section, the performance of the model and the main effects are discussed. The first level of each attribute that is significant in an initial multinomial logit model estimation enters the model as random parameter in the final mixed multinomial logit model estimation. Looking at the goodness of fit statistics (Table 46) the model with a ρ^2 adjusted of 0.286 fits the choice data well as the ρ^2 adjusted value is higher than 0.2 (Louviere et al., 2000).

Table 46 Goodness of fit statistics mixed multinomial logit model

Parameters	32
Log-likelihood function LL(β)	-474.33
Restricted log-likelihood function LL(0)	-682.24
ρ^2	0.305
ρ^2 adjusted	0.286
Akaike information criterion (AIC)	1,012.70

In the mixed multinomial logit model estimation results (Table 47), the 'constant' and main effects for the attributes 'networking and training' and 'cost plus 10%' are significantly random, which indicates that the utility for these attribute levels vary among decision-makers. The 'constant' parameter, which represents the base utility of selecting the opt-out option is positive and its utility varies among firms. As expected, among the decision-makers there exist utility differences in terms of their current location. Moreover, the heterogeneity of the cost parameter indicates significant differences in the evaluation of costs. This underscores the many unobservable factors that influence the respondent's real-life cost (Geltner and Miller, 2001). The differences in utility found for the events attribute, 'networking and training', could be explained that for some firms these are less useful than for others. Training events are in general catered to and specifically useful for younger firms (Albahari et al., 2019). However, for the current study, no significant interaction effect of firm size or firm age was found (see section 6.4.3.2). For networking events this could be related to the social personality of individuals which may vary between firms (Koçak and Can, 2013).

Table 47 Mixed multinomial logit model main effects

Attribute	Attribute levels	Coefficient (β)	Standard Deviation
	Constant (not relocate)	**0.826	***2.714
Location	Station location	-0.001	
	Suburban location	*****0.372**	
	Highway location (reference)	*-0.371*	
University	**University in the same area**	*****0.618**	
	University in the same city	-0.009	
	University in a different city (reference)	*-0.609*	
Firm diversity	All technology domains	*0.217	
	A limited number of technology domains	***-0.461	
	The same technology domain (reference)	***0.244***	
R&D facilities	Shared usage of R&D facilities	*0.207	
	R&D facilities for private use	*****0.370**	
	No R&D facilities (reference)	*-0.577*	
Shared facilities	Shared business and leisure facilities	*0.222	
	Shared business facilities	****0.255**	
	No shared facilities (reference)	*-0.477*	
Events	Networking and training	-0.013	***0.590
	Networking events	****0.270**	
	No events are held (reference)	*-0.257*	
Cost	Cost plus 10%	***-1.222	***0.618
	Cost same as current	0.102	
	Cost minus 10% (reference)	***1.121***	

Note. ***, **, * significance at 0.01, 0.05 and 0.10 level respectively.
Bold values indicate highest part-worth utility.
Italicised values indicate referenced attribute level.

Furthermore, the parameters in bold indicate the attribute levels with the highest β-values which means these represent the highest utilities for respondents for each attribute. The parameters in italics indicate the utilities of the reference levels that were calculated for each attribute based on the estimated utilities of the other levels, as explained. The negative sign of the highly significant 'cost plus 10%' means that respondents do not prefer to pay more, which is not surprising.

In the next sections, the main effects, the willingness to pay and the impact of interactions effects on utilities are further discussed.

6.4.3.1. Main effects and willingness to pay

The mixed multinomial logit model results allow for the estimation of the relative importance value and the willingness to pay for all attributes. However, previous non-significant part-worth utilities should be interpreted as having no effect, i.e., its utility does not deviate significantly from zero. Therefore, the part-worth utilities are set to zero for the not-significant parameters of 'station location', 'university in the same city', 'networking and training' and 'cost same as current'. These part-worth utilities were already close to zero initially (see Table 47).

The relative importance of an attribute (for the choice of location) is indicated by the size of the utility range across the levels of the attribute: the larger the range the larger the impact of the attribute on the overall preference value for the choice of location. The total range of the utility of the cost attribute is the highest with 2.44, which is derived from the highest negative value and the highest positive value of the part-worth utilities. In the same manner, the size of the utility range of all attributes are derived from their respective part-worth utilities (Table 48). As expected, cost of the location is the most important aspect (Chan and Lau, 2005; Audretsch et al., 2005). Besides the cost attribute, the highest impact design-related attribute is 'university' followed by 'R&D facilities', 'location', 'shared facilities', 'firm diversity' and lastly 'events'. The utility impacts for 'location', 'shared facilities' and 'firm diversity' are similar and therefore are somewhat equally important for tenant firms.

Table 48 Utility and willingness to pay science park attributes

Attributes	Part-worth utility	Size of utility range	
Cost		**2.44**	
Cost plus 10%	-1.222		
Cost same as current	0		
Cost minus 10% (reference)	*1.222*		
Design-related attributes	Part-worth utility	Size of utility range	wtp (%)
1. University		**1.24**	**10.11**
University in the same area	0.618		5.06
University in the same city	0		0
University in a different city (reference)	*-0.618*		*-5.06*
2. R&D facilities		**0.95**	**7.74**
Shared usage of R&D facilities	0.207		1.70
R&D facilities for private use	0.370		3.02
No R&D facilities (reference)	*-0.577*		*-4.72*
3. Location		**0.74**	**6.08**
Station location	0		0
Suburban location	0.372		3.04
Highway location (reference)	*-0.372*		*-3.04*
4. Shared facilities		**0.73**	**5.99**
Shared business and leisure facilities	0.222		1.82
Shared business facilities	0.255		2.09
No shared facilities (reference)	*-0.477*		*-3.91*
5. Firm diversity		**0.71**	**5.77**
All technology domains	0.217		1.77
A limited number of technology domains	-0.461		-3.77
The same technology domain (reference)	*0.244*		*2.00*
6. Events		**0.54**	**4.42**
Networking and training	0		0
Networking events	0.270		2.21
No events are held (reference)	*-0.270*		*-2.21*

Note. Italicised values indicate referenced attribute level (i.e., the zero-point).

The wtp values should be interpreted as what percentage of the total current cost, firms are willing to pay to change from one level to another level. For instance, if firms are currently located in an area with a university in a different city then they are willing to pay 10.11% more for an alternative with a university in the same area, while holding all else equal.

Looking at the design-related attributes, the relative highest part-worth utility is represented by 'university in the same area', followed by 'in the same city' and lastly 'in a different city'. The degree of proximity of the university is in line with previous work of Ferguson and Olofsson (2004) and Dettwiler et al. (2006). This attribute might be attractive for financial reasons. It provides firms access to potential highly educated recent graduates for relative low cost (Audretsch and Lehmann, 2006). Moreover, possible unintended knowledge spillovers are generally less expensive than formal agreements (Chan et al., 2011).

The results show that when firms are given the choice of none, shared or private use of R&D facilities the most preferred areas are those that allow for private use, which does not outweigh the possible advantages of the shared use of these facilities. Firms that currently do not have access to R&D facilities are willing to pay 7.74% more for alternative locations that offer R&D facilities for private use. Firms are likely to be more focused on conducting their core activities and prefer secrecy within the R&D settings (Dettwiler et al., 2006). The second most important R&D attribute level is the shared use of these facilities among different firms. The face-to-face interaction between different organisations has been researched as means to build trust and knowledge (Storper and Venables, 2004; Ramírez-Alesón and Fernández-Olmos, 2018).

For the relatively urbanised station location no significant part-worth utility is found, while firms do prefer the 'suburban location' more, where both the station and the highway entrances are somewhat close by. American metropolitan areas are in general attractive for firms for their access to human talent and facility mix (Florida, 2014). However, the polycentric nature of the Dutch context is reflected within the findings that firms prefer suburban locations more where the distances are relatively small (Burger and Meijers, 2012). Firms currently located at highway locations are willing to pay 6.08% more to relocate to suburban locations

For the shared facilities, all part-worth utilities are significantly different from zero. Technology-based firms prefer areas with only shared business support facilities the most, followed by shared business support and leisure facilities (e.g., cinema, sports facilities), and they least prefer areas where no shared facilities are provided. Firms with no access to shared facilities are willing to pay 5.99% of their total current cost to upgrade to an alternative location with shared business facilities. The shared use of facilities and services has been suggested to provide for opportunities for cost saving and collaboration with others (e.g., Chan and Lau, 2005; Brinkø et al., 2014). Evidence from the Netherlands revealed that the possible benefits of meeting new people on science parks through shared resources and facilities are known to tenant firms, but at a high cost (Van Der Borgh et al., 2012). The results show that while science parks can choose to provide more expensive shared facilities to tenants, they seem to prefer the shared use of R&D facilities and business support and leisure facilities to some extent, but the private use of R&D facilities is the most preferred option.

Among the levels of the 'firm diversity' attribute, firms are more willing to pay for areas that at least host firms that are in the same technology domains as them. Followed by areas with a wide focus on all technology domains and lastly with a narrow focus. This suggests firms first and foremost prefer to exploit their current core activities, which could reduce risks (Renski, 2011). While collaborative opportunities with firms from different backgrounds comes second (Lamperti et al., 2017). As a collective of firms with different backgrounds such areas could therefore tap into a wide pool of knowledge and allow for exploration of new technological fields (Adner and Kapoor, 2010; Van Der Borgh et al., 2012). However, risks might arise from cognitive distance and the lack of absorptive capacity between firms from different fields (e.g., Boschma, 2005; Ubeda et al., 2019). The higher preference for so-called 'specialised' science parks are suggested to be beneficial for firm investments, while the relatively less desired 'general' science parks could be related to attaining sales goals (Liberati et al., 2016).

Lastly, areas providing relevant networking events is most preferred, followed by networking and training events and least preferred are areas which provide no events. Firms that do not have access to any events are willing to pay 4.42% more for alternative locations where networking events are held. The general purpose of these networking events is likely to share knowledge, seek out collaboration opportunities and to get closer to people from academia and industry (Ng et al., 2019b). Specifically, for smaller firms the dependence of networks is essential to gain access to market and technological knowledge for improving the firm's product offering (Van Der Vrande et al., 2009).

6.4.3.2. Interaction effects

Besides the main effects, the interaction effects include the effects between two attributes and the effects between an attribute and a covariate and allow for a further investigation of the attributes and possible differences in preferences among decision-makers related to firm characteristics. The estimation results on this level are shown in Table 49. The utility of an alternative that is located in the suburbs with a university within the same area increases with 0.372 and 0.618 respectively through the main effects and the two-way interaction increases the overall utility with 0.345, which results in a total utility of 1.335. An alternative with the university close by (0.618) that focuses on a limited number of technology domains (-0.461) receives an additional utility through its two-way interaction (0.216), but has a relatively lower total utility (0.373).

Table 49 Interaction effects attributes and covariates mixed multinomial logit model

Interaction effects - attributes ($x_{jj} * x_{jj'}$)	Coefficient ($\delta_{jj'}$)
Suburban location * University in the same area	***0.345
University in the same area * A limited number of technology domains	*0.216
Interaction effects - covariates ($x_{ji} * z_{kn}$)	Coefficient (δ_{jk})
Station location * science park firm	***0.273
University in the same area * science park firm	***0.418
Shared business and leisure facilities * science park firm	*0.182
Suburban location * firm size - less than 10 employees	***-0.351
Cost same as current * firm size - less than 10 employees	***-0.294
A limited number of technology domains * firm age - between 5 to 9 years	**-0.242
Cost same as current * firm age - between 10 to 19 years	**0.234
Suburban location * currently located in station or suburban area	***0.299
University in the same area * high technology sectoral focus	**-0.222
Cost plus 10% * prototype development & testing technological R&D	*0.264
Suburban location * launch technological R&D	***-0.334
Cost plus 10% * access to meeting rooms	*0.340

Note. ***, **, * significance at 0.01, 0.05 and 0.10 level respectively.

For the interaction effects between attributes and covariates, descriptive characteristics of the decision-maker such as 'science park firm', 'firm size', firm age', 'location', 'technological sectoral focus', 'prototype development & testing', 'launch' and 'access to meeting rooms' significantly increase or decrease the utility in conjunction with specific attribute parameters.

Tenant firms already located on science parks prefer station locations and a university in the same area more than off-park counterparts. This preference of existing park tenants towards a university is in line with the work of Díez-Vial and Fernandéz-Olmos (2015). Furthermore, the science park location also leads to more preference to areas with shared business support and leisure facilities. Moreover, the Pearson correlation test (section 6.4.2) showed that the 'science park firm' covariate is correlated with other variables (i.e., access to a wide range of facilities and that science parks especially attract smaller firms, while larger firms are significantly less present). These findings are in line with Dettwiler et al. (2006) that park tenant firms have access to more facilities and services than off-park counterparts and that they value these shared facilities and services. Their facility management framework is extended through outlining which other aspects are meaningful while considering other covariates.

Furthermore, smaller firms prefer suburban location and areas with similar cost as their current situation relatively less. Both effects are likely to be related to financial motives. These new technology-based firms might want to target local markets and therefore locate further away from urban areas (Baptista and Mendonça, 2010). Smaller firms are more likely to find suitable space for their operations in less expensive locations. Saving housing costs allow new technology-based firms to redistribute their funds to their core activities (Durão et al., 2005). The high costs of science park services experienced by new technology-based firms have been reported by Westhead and Batstone (1999) and Chan and Lau (2005).

For younger firms (between 5 to 9 years) a relative lower preference is found for alternatives with a focus on a limited number of technology domains, which for the main effects is the least preferred level of this attribute. These firms prefer alternatives focused on a large range of technology domains (including their own) in order to explore new technological fields where more opportunities are available (Almeida and Kogut, 1997). For relative older firms (between 10 to 19 years) the total costs should stay the same as they prefer affordable options. Furthermore, firms already located in a station or suburban location do prefer suburban locations more in their decision-making process.

Firms who are focused on one or two technological sectors prefer areas which are closely located to a university less. This is especially interesting as the main effect of this university attribute parameter represents the highest part-worth utility. For these firms, the close geographical proximity seems less important. When considering other proximity dimensions, the lower utility could be explained as that these specialised firms have different processes (institutional distance) or are focused on select domains, while universities often conduct research in a wide array of domains (cognitive distance) (Boschma, 2005). Potential obstacles of knowledge transfer between universities and firms could be unawareness, secrecy or a lack of commercial or academic interest. Moreover, the firm's research activities might fit commercial goals, but may not be of interest for academia (Woerter, 2012). Repeated interactions between firm and a university are beneficial in accumulating absorptive capacity (Díez-Vial and Fernández-Olmos, 2015), but recent work of Ubeda et al. (2019) showed that too much absorptive capacity might reduce mutual learning.

Firms active in developing and testing prototypes are less sensitive to rent price (costs) in the choice of location. The iterative process of prototyping and testing of new innovations tends to be expensive and risky as not all efforts can be valorised. However, these uncertainties could be limited if simultaneous and consecutive prototyping is possible (Teece, 1986). These firms are likely to acknowledge the uncertainties of these types of activities and therefore expect that more expensive locations represent more quality that could aid their business. It should be noted that the current explanation is found within the mental perception of the decision-maker as the alternatives within the experiment are only different through the attributes and their levels.

Moreover, firms active in launching innovations into the market prefer suburban locations less than those firms not active in launching innovations. This could be explained as that for launching commercially viable products, more space is required, in which the rent for areas closer to city centres are generally higher.

Lastly, firms that currently have access to meeting rooms prefer alternatives that are relatively more expensive. It is noted that the meeting room variable is positively related with being located on a science park. The rents on science parks are generally higher than market prices, which might suggest that firms that have access to these facilities are used to the more expensive choices.

6.5. Conclusion and limitations

This study's contribution to innovation policy is the study of stated preferences of Dutch technology-based firms in the context of hypothetical location choice situations. The hypothetical location alternatives presented in the choice experiment possess typical science park attributes related to the location, proximity to university, firm diversity, facilities and services offered. The use of a stated choice framework with a priori defined science park design profiles allows for utility estimation of all attributes and their levels. Existing science park literature mainly focuses on the revealed preference in order to prove policy effectiveness with mixed evidence (Albahari et al., 2010). In these studies, limited attention is given to the science parks, while these parks can be very different in terms of characteristics, which makes evaluation of their effects challenging (Etzkowitz and Zhou, 2017; Ng et al., 2019a). The current results fill knowledge gaps in relatively novel research directions within the science park literature; the study of perceptions or stated preferences of firms (Albahari et al., 2019; Lecluyse et al., 2019) and the development of science parks (Mora-Valentín et al., 2018). In a broader perspective, although typical science park characteristics are used, the results have implications for other knowledge-based area developments too and the preferences of technology-based firms in general.

The unique choice data of 69 technology-based firms in the Netherlands of which half are located on science parks and half are not, reveal that costs remain the prime consideration in location choice within the range of attributes considered in the study (Chan and Lau, 2005). The university presence is the second-most important consideration, followed by R&D facilities, location type, shared facilities, firm diversity and, lastly, events. As these design-related attributes are derived from prior literature they were expected to be relevant to firms to some degree. The significant results of at least one level of each considered attribute confirms this. Moreover, the discrete choice modelling adds to previous research through estimating the trade-off among all seven attributes used. Although characteristics of real-life alternatives are largely interwoven with their location (i.e., transportation options, distance to the university and space for facilities and services), the current stated choice approach disentangles the separate utility effect of each attribute. Multiple authors in the science park field have posited the acknowledgement of the heterogeneity among science park tenant firms (e.g., Chan and Lau, 2005; Ubeda et al., 2019).

Through the mixed multinomial logit model the heterogeneity was considered among preferences of technology-based firms. The use of an off-park group reduces the selection bias of the science park tenant firms as they already have made the choice to locate on these parks (Siegel et al., 2003b; Vásquez-Urriago et al., 2016). Furthermore, preference differences are captured through the inclusion of organisational characteristics and the random parameters in the model. It shows that technology-based firms already based at science parks have access to a wider range of facilities and appreciate the close presence of the university, the provision of shared business support and leisure facilities more.

They also value alternatives close to station locations and are willing to pay more for these characteristics. This study answers to some degree why technology-based firms would choose to co-locate (Stuart and Sorenson, 2003). Considering the attributes used, they prefer locations that are close to the university and for their R&D activities they prefer facilities for private use. These preferences for these attributes are likely tied to the university as a potential source of knowledge and the private use of facilities might allow tenant firms to focus on their core business activities. Moreover, they prefer areas moderately accessible through train and car in the suburbs. Furthermore, they prefer areas that at least focus on their own technology domain, shared usage of business support facilities and networking events.

Although the findings refer to aspects that are difficult to change in real-life (i.e., location type or proximity of university), strategic choices remain concerning how to operate these science parks. The results are especially interesting for policy-makers for new science park development, but also provide existing science parks with strategic insights in technology focus and the provision of facilities and services. Considering that only a small fraction of the sampled firms is currently located at science parks near station locations, more attention should be given to this unfulfilled need for centrally located knowledge-based areas with adequate means of public transportation. For science park management a crucial role is required for facilitating the interaction between firms from different technology fields in order to avoid cognitive distance and enable mutual learning. Moreover, as the utility differences suggest, the organisation of networking and training events should require attention that caters to specific people and firms (Koçak and Can, 2013; Albahari et al., 2019). For universities, the results show that technology-based firms value their presence. In contrast, technology-based firms currently not located on science parks prefer the proximity of a university relatively less. Therefore, for universities that want to attract new firms to their campus, more effort is required to convey their added value towards new tenants. For practitioners, this study allows for benchmarking new and current science parks and knowledge-based area developments through the utility estimation of the considered attribute levels.

Naturally, this research is not without limitations, which opens potential future research avenues. First and foremost, the small sample size did not allow for segmenting groups based on preferences (i.e., latent class analysis). Furthermore, due to the small Dutch sample of technology-based firms the results are not representative for the population of technology-based firms in the Netherlands. Moreover, the use of hypothetical science park alternatives with a restricted number of attributes comes with some drawbacks.

The unnamed alternatives are not tied to existing places and the image or brand of science parks are not considered. For younger firms, image benefits are especially important in order to enhance their legitimacy (Ferguson and Olofsson, 2004; Ng et al., 2019b). Essential issues of supply and demand of real estate are the inelasticity of the former and the dynamic nature of the latter. In this sense, Díez-Vial and Fernandéz-Olmos (2017) argued that the value of science parks changes over time, which asks for longitudinal research into the dynamic needs of its users. Other researchers are encouraged to continue investigating the demand of technology-based firms while considering contextual factors such as duration of stay on their current location. Furthermore, recently, science park management size has been found to be positively related to tenant firm's innovation performance (Albahari et al., 2018).

Future research could delve into the impact of the science park management and include labelled alternatives related to real-life places. However, for labelled choice experiments, more design profiles are required and real-life alternatives might lead to many unobservable factors that impact the firm's decision-making.

Although the precise conditions that enable science parks to be successful remain unknown (Yang et al., 2009), this study reveals the discrete conditions of science parks that fit the needs of its users. Closing the gap between the tenants' demand and science park configuration is beneficial for both science park managers and tenant firms for achieving both parties' goals, increase performance and possibly attract new tenant firms (Albahari et al., 2019).

PART IV

Conclusions
Implications

CHAPTER SEVEN

Conclusions and Implications

In this final chapter the key results from this dissertation are summarised. First, the main aim and research questions are discussed and in what way these questions are addressed. Then in section 7.2, the theoretical and practical implications of this thesis are discussed. Finally, the limitations and possible new research lines are proposed in section 7.3.

7.1. Summary and findings

The main aim of this thesis is to identify different science park types among the supply-side, and to analyse the needs and trade-offs of different tenant firms with regard to design-related science park attributes in order to provide input for the development and management of science parks that fit the needs of the different tenant firms. Through this thesis the heterogeneity among science parks and its tenant firms was considered with regard to what is offered and what is sought for. This allows for advancing the debate surrounding the effectiveness of science parks and provides a clearer image of what science parks are and what they could do for their tenants.

The overall research question as formulated in chapter 1 is: *"Which types of science parks can be distinguished and what are the perceived benefits and trade-offs of science park tenant firms with regard to important science park attributes?"*

The main research question was independently studied through four data collections and analyses.

In the first study, the potential heterogeneity among science parks was addressed through a cluster analysis among European science parks, which led to a science park typology based on their (dis) similarities. To do so, an online survey was completed by 82 science park managers across 17 European countries. The results led to the segmentation of three significant different science park types: 'incubator locations', 'research locations' and 'cooperative locations'. This typology is what makes these existing science parks distinct through seven characteristics. These characteristics in order of importance for classification are: presence of research institutes, presence of higher educational institutions, presence of (shared usage of) laboratories, mix of leisure facilities (e.g., sport facilities, cinema), surface area, mix of other facilities (e.g., banking, child care, medical, residential housing, shops) and lastly, ownership. Compared to existing research, this study showed that when a larger range of clustering variables is considered, the knowledge-related aspects of science parks are highly distinctive, while facilities/services and ownership structure are relatively less essential for distinguishing science park types. Looking at the snapshot of European science parks a new definition of what science parks are, was formulated.

"A science park is a real estate or area development, managed by an on-site management company. It is home to knowledge organisations, such as research institutes, higher educational institutions 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 science park typology consisting of incubator locations, research locations and cooperative locations can be distinguished." It is noted that this sub study explored what science parks 'are' (i.e., makes them distinct), but not what they 'do' for tenant firms.

The second and third sub studies aimed to reveal what science parks can 'do' for tenant firms. In order to support a further conceptualisation of science parks, a means-end approach was chosen. Within this thesis, the 'ends' for tenant firms are the potential benefits that they can attain through the 'means', which are that what a science park can offer to them.

In the second study the 'means' consisted of an a priori defined list of facilities/services and the 'ends' were the perceived benefits. The association data between facilities/services and perceived benefits of 103 science park tenant representatives in the Netherlands allowed for the investigation of the perceived impact in relation to these attributes. In this study three science park tenant types were found through a cluster analysis based on different organisational characteristics. These types are: 'commercially-oriented firms', 'mature science-based firms' and 'young technology-based firms'. Some differences were found among tenant types with regard to the benefits they seek. The first group is more interested in being near their clients. For the other more technology and science-based firms, image benefits are important. The more mature firms value the close proximity of university, customers and similar firms more, while younger firms are more cost-driven. The results suggest that the needs towards certain aspects of a science park differ among the large range of science park tenant firms. Firms in general expect to gain knowledge sharing and collaboration opportunities through training programs. Moreover, business networking services are seen as means to be near the university, customers and other firms.

In the third study, the facilities/services attributes were extended with more real estate related attributes and proximity attributes (towards specific actors) and managerial attributes. Accordingly, the perceived benefits used in this study were also expanded to fit the wider range of attributes. These perceived benefits include typical economical, innovation and networking-related performance indicators. This study revealed which of these indicators are the most important within the perception of tenant firms and therefore require more attention in future studies and in practice. 51 science park tenant firms in the Netherlands recalled important science park attributes in an open format and were asked to match their free responses with a list of attributes as emerged from the literature review. This method expanded upon the second study as richer data were obtained on these attributes. Subsequently, these respondents were asked why these attributes are important through their association with the list of benefits. The six most important benefits are in order: attracting human talent, increased sales, cost saving, attracting funding for growth/innovation, develop ties with other firms and lastly, new products/services. The results indicate that specific attribute groups serve different perceived benefits.

Tenant firms associated proximity and managerial attributes with all three categories of economic, innovation and networking benefits, while the majority of real estate attributes were only associated with economic benefits. The absent link between networking benefits and any real estate attributes was especially interesting as existing research has posited the relation between co-location, networking and subsequent knowledge sharing. According to tenant firms, science park management is relevant and in particular for the activities that enhance social interaction. Developing ties with other firms was associated with the science park management attribute itself, but also community building, providing access to regional and international networks and the creation of an entrepreneurial climate.

The fourth study concluded with the trade-offs that technology-based firms make among seven typical science park attributes. Through the use of a control group of off-park firms, the specific preferences of science park tenant firms were revealed. A stated choice experiment, involving relocation choice tasks with two hypothetical science park locations and the choice to not relocate, was completed by 69 technology-based firms. This experimental approach allowed for the independent estimation of the utility that tenant firms assigned to the considered attributes. In total seven attributes with each three attribute levels were used to describe the hypothetical science park alternatives. In real-life, location-related attributes are largely interwoven and therefore the individual utility of specific attributes is difficult to determine. Examples of these interwoven attributes include location of the university with urban context and the limitations/ possibilities of the physical size of the area. Furthermore, heterogeneity among respondents was taken into account through random parameters in the mixed multinomial logit model and the inclusion of interaction effects related to the organisational characteristics of the decision-makers. Considering the seven attributes used in the stated choice experiment, the most important aspect is cost of use, followed by the proximity of a university, R&D facilities, location type, shared facilities, sectoral focus of other firms and lastly events organised. The estimated utility values of attribute levels were used to determine the willingness to pay for each level. The policy effectiveness of science parks was revealed to some degree as science park tenant firms preferred locations near stations and with a university within the same area relatively more than off-park counterparts. In addition, these tenant firms already located on science parks valued the provision of shared business support and leisure facilities on science parks more than off-science parks firms.

7.2. Implications for theory and practice

The key theoretical issues surrounding science parks raised in the first chapter are: the need for a further conceptualisation, limited knowledge on perceptual measures (i.e., needs) and mixed evidence on their impact. Furthermore, in this section the specific implications for practice are also highlighted through discussing advice for policy-makers, real estate practitioners, science park management, universities and firms based on the findings.

7.2.1. Theoretical implications

From a positivist view, this thesis followed structured empirical steps to attain the research objective as posited in chapter 1 and reiterated in this chapter, whilst considering the existing literature. The theoretical contributions of this thesis are threefold.

Firstly, this thesis contributes to the further conceptualisation of science parks. Existing evaluative research of science park firm performance has used 'science park location' and supplementary characteristics as firm variables in order to prove the policy effectiveness of science parks (e.g., Fukugawa, 2006; Squicciarini, 2008; Liberati et al., 2016). In those studies, the science park effect is mainly operationalised through whether the firm of interest is located on or off a science park, through the science park size and/or the sectoral focus of the science park, etc. The typology study in this thesis empirically reveals that statistically different science park types exist when considering among others the presence of research institutes and university and science park size for the provision of facilities and services. This implies that researchers should pay more attention to the characteristics of the science park location of sampled firms. Recently, Corrocher et al. (2019) considered science park characteristics, such as presence of research networks and park size when comparing the performance of on- and off-park firms. This dissertation further underscores their finding, as the most important variables that distinguish science parks are the knowledge-intensive characteristics and to a lesser extent size-related characteristics and ownership structure. Moreover, the location choice study in this thesis also measured the trade-offs firms make between a number of attributes, while circumventing some drawbacks of using real-life cases (i.e., disentanglement of individual utility effects of related attributes, revealing of the influence of difficult to ascertain aspects). This revealed within the perception of technology-based firms, science parks indeed have developed beyond mere real estate properties. Specifically, the proximity of a university is more preferred than the accessibility of the location, which is one of the typical key consideration of real estate properties. Furthermore, the results reveal that significantly different tenant types exist in terms of organisational characteristics and what they seek. This suggests that future attempts for classifying science parks could consider the composition of tenant firms as an additional classifying characteristic. Although future science park classification attempts with a larger sample of science parks could provide for a more informative segmentation (i.e., allow for more cluster variables), the current findings might already aid future researchers interested in evaluating science parks. While considerable attention is given to matching on- and off-park firms on comparable firm characteristics within existing studies, the insights of the typology might make a more effective matching of comparable science park locations possible. This in turn could lead to more rigorous evaluation research and more clearly defined policy recommendations.

Secondly, this study contributes in particular to knowledge on the demand-side of science parks by using perceptual measures. Lecluyse et al. (2019) argued that perceptual measures are better able than traditional performance indicators to account for the different objectives of the wide range of tenant firms on science parks. This thesis studied perceptual measures within the science park context through focussing on tenant firms' perceived benefits and the means to achieve those benefits. The first perceived benefits study reveals that science parks are indeed home to different types of tenant firms in the Netherlands, which seek different benefits through different science park facilities and services. As suggested by Chan and Lau (2005), this thesis proved that the heterogeneity among tenant firms on science parks should be accounted for in future research. The second perceived benefit study revealed that real estate attributes are not associated with networking and innovation-related benefits, but only with economic benefits.

This suggests that the direct impact of knowledge sharing benefits in the built environment on the science park level is limited and that other factors should be considered such as presence of research institutes/universities, management function and provided business networking and training events. Some science park types provide shared use of facilities and a certain park size/layout, which might contribute to the number of chance encounters among employees from different firms and subsequent knowledge transfer (Dettwiler et al., 2006). In contrast, the stated choice experiment results show that private R&D facilities are more preferred than shared R&D facilities by firms. The presumption of co-presence and subsequent knowledge transfer is therefore somewhat challenged by the results of this study as this relation might not be easily facilitated by certain science parks and was absent within the perception of the tenants. Furthermore, potential obstacles such as social and cognitive proximity could also be barriers for knowledge sharing among people from different organisations (Boschma, 2005).

Lastly, possible explanations for the mixed evidence of science parks with regard to the performance of tenant firms are revealed through investigating the demand-side of these park tenant firms. The mixed results in existing research on economic and innovation output could be attributed to neglecting the existence of both the heterogeneity among science parks and among its tenant firms. Across three sub studies (i.e., typology, perceived benefits of facilities and services and stated location choice) the heterogeneity among science parks and science park tenant firms was considered. Recent science park research has posited the importance of taking into account that science parks and firms on these parks are not that homogenous (e.g., Fukugawa, 2013; Díez-Vial and Fernández-Olmos, 2015; Liberati et al., 2016; Ubeda et al., 2019). The current typology with the refined science park definition could benefit past and future researchers in evaluating science parks and its tenant firms more adequately. Similarly, the acknowledgement of statistically different tenant types on science parks provides for new insight for the sampling procedure in science park research and the consideration of organisational characteristics as explanatory variables. Moreover, for future science park evaluation research, the study into perceptual measures revealed that more attention should be given to indicators that can effectively operationalise important perceived benefits like 'human talent' and 'cost saving'. Within existing science park evaluation research, 'cost saving' is considered a science park feature and has therefore not been operationalised as a performance indicator yet. This study also showed that younger firms perceive 'cost saving' to be more important than their older counterparts. Dettwiler et al. (2006) argued that new technology-based firms outperform off-park firms through contractual agreements and the access to shared park facilities and services, which leads to financial advantages compared to firms not located on science parks. Future studies comparing the science park effect on the performance of especially new technology-based firms should consider this park effect with regard to 'cost saving' measures through the use of park facilities and services.

Stepping outside of the science park context, some suggestions can be considered on the future exploration of co-presence of firms and the unclear link with knowledge transfer among these firms. Science park tenant firms did not perceive the link between the use of real estate with networking and subsequent knowledge sharing or innovative benefits. In contrast, services such as networking events and training programs were associated with knowledge sharing benefits.

This further underscores the importance of conducting additional research on science park management teams as they are likely to be able to connect the right people and further strengthen the awareness of the benefits of the science park. In addition, the science park management function was perceived by tenant firms to be linked with networking benefits. Existing research has posited that repeated social interaction could lead to knowledge transfer and possibly innovation-related benefits (e.g., Storper and Venables, 2004; Díez-Vial and Fernández-Olmos, 2015). This suggests that science park management could fulfil an indirect role of stimulating innovation. Therefore, future research into innovativeness of managed science parks should consider longitudinal approaches in order to observe the impact of the science park management over a longer period.

7.2.2. Practical implications

From a pragmatic view, science should serve practice and initiate practical action (Saunders et al., 2018). Consequently, implications are addressed specifically towards actors active in the science park field: policy-makers, real estate practitioners, science park management, universities and firms.

In essence, science parks were established as policy tools to induce networking, innovation activity and subsequent economic output. The differences among science parks and firm types suggest that policy-makers should acknowledge that not one model of the science park exists. Specifically, this group plays an important role in allocating public resources towards new science park development. In addition, attention should be given to locations that are of interest to tenant firms. The geographical proximity to research institutes, similar firms and especially a university are important determinants of locations that fit the needs of firms. To some degree this thesis highlights the policy effectiveness from the perspective of the tenant firms. Compared to off-park counterparts, science park tenant firms value the close proximity of university, station locations and shared business support and leisure facilities, more. As the majority of the sampled science park tenant firms are located at highway locations, this urges policy-makers to consider additional measures to improve the means for public transport at current and new science park locations.

The second actor to whom advice is directed consists of the real estate practitioners, which includes investors, project and concept developers. The typology of science park types provides investment parties additional insights in evaluating future alternatives. In the real estate business, properties with similar attributes can vary in their value among locations, due to a wide range of factors. The location choice study showed that among the considered attributes, technology-based firms valued the close proximity of a university relatively more than the transportation options of the location itself.

Investors interested in funding science parks should therefore seek out locations on existing university campuses. Furthermore, this study revealed that tenant firms pursue a wide range of benefits, which partly could be facilitated by a dedicated science park management, where park management and business development should be aligned. For real estate developers that are setting-up new science park projects the segmentation of tenant types is especially interesting. On the one hand it provides the characteristics of potential target groups, while on the other hand their needs are revealed including the means in the form of science park attributes that are required to achieve these needs. Overall the exploration of science park types and linking attributes and benefits aids these practitioners with the adequate design, development and evaluation of science parks.

Existing research has paid attention specifically to the management of science parks. The study on perceived benefits showed that tenant firms are seeking a wide range of benefits and a vital role is reserved for science park management. Especially, for science park management, a large gap between what they offer and what tenants want is troublesome, as this could lower their satisfaction or even worse, lead to their departure from the science park. Tenant firms expect the daily operations, such as park management as means for attaining liveability and image benefits. Furthermore, they see science park management as facilitator of networking among resident organisations. These repeated interactions between firms could ultimately contribute to innovation. The wide range of needs suggests that more attention is required in getting the right firms together and in touch with one another. That is to say that the cognitive proximity between actors should be sufficient to allow for mutual learning. Science park management could selectively choose tenant firms that fit the science park profile or facilitate networking between resident firms and external organisations. Tenants did not perceive a link between real estate attributes and networking benefits. This suggests that co-location and interacting with other firms occur somewhere else or that the link between the facilities/services and networking is not (yet) apparent. Additional effort from the science park management is therefore crucial to inform and connect tenant firms with relevant partners.

Through all sub studies the role of the university is among the most important to distinguish science park types and also most valued by tenant firms. Technology-based firms located on science parks preferred the close proximity of the university even more than off-park counterparts. Existing literature suggests that the university can act as a source for knowledge, collaborations or human talent. In contrast, this also means that technology-based firms currently not located on a science park still need more convincing arguments on the added value of the university. Furthermore, additional analysis revealed that technology-based firms that are highly focused on a limited number of technology sectors preferred the close proximity of a university relatively less. As these firms probably are familiar with the leading researchers of their specific fields, they might have a lower tendency to physically locate near universities. If a university wants to collaborate or attract these firms to their campus, they should therefore tap into the network of their leading professors and researchers to get closer to these firms. From the perspective of a university, attracting new technology-based firms could provide for new research collaborations, internships and work opportunities for students and potential image benefits from well-known firms.

Lastly, this thesis has implications for the main user groups of science parks, namely the firms. The typology of science parks provides firms with insight in the differences among potential new locations for operation. One of the key features of science parks is the management function that allows firms to focus on their core business and to network with other organisations. These features could contribute to their innovation activities on the long term. This thesis showed what science parks are and what they potentially can do for firms. Firms with an intention to move could therefore investigate and inquire on the services that potential science parks can provide for them. The last study on location choice provides firms with a general overview of location preferences of peers as relocating operations are often major business decisions, which affect their workforce and physical assets.

7.3. Limitations and future research

Positivist research, which aims to develop knowledge through measurable facts, largely relies on data (Saunders et al., 2018). Each of the four sub studies relied on its separate data collection and a reoccurring issue is relatively small samples. Despite sending multiple reminders towards the target respondents, often executive level decision-makers of technology-based firms, the response rate generally remains somewhat low. For the typology study, a large number of science parks in the sample are located in the Netherlands and the UK, while typical science park countries, such as France and Germany are less well represented. Also, Eastern European countries are less represented, which might be related to language issues. Future research could adopt a multilingual approach towards underrepresented regions. Moreover, a large part of this thesis focused on firms located in the Netherlands. As the sample size per data collection is relatively small the overall results are not necessarily representative for all firms in this country.

The means-end approach for the investigation of the causal relation between science park attributes (means) and benefits (ends) poses a philosophical limitation. Within chapter 4 and 5, representatives of tenant firms associated these relevant means to specific ends. The former focused on means in the form of facilities and services, while the latter focused on the wider range of means including proximity, real estate and managerial attributes. Firm behaviour and therefore human behaviour are continuous (Dewey, 1938). This results in that an end cannot have an endpoint. That is to say that these ends or benefits will continue to serve additional subsequent purposes or objectives for these firms. As Dewey (1938, p. 36) posited: "Means and ends are two names for the same reality. The terms denote not a division in reality but a distinction in judgment". Both chapters adopted a different set of means and ends, which could allow for some room of judgment for what dictates a mean and what an end. The chosen method of an a priori defined list of facilities/services and benefits for the former study could be restrictive to what entails means and ends as presented by the researcher. However, the method of recalling and recognising attributes discussed in chapter 5 limited this issue to some extent. The present study into the associations between perceived benefits and attributes produces a first overview of the links and the motivations of tenant firms (i.e., link strength between these means and ends). Future interpretive research could complement the results and adopt a more qualitative approach that allows for a deeper understanding of these ends. Another continuation of the current approach could be using recalling techniques for the list of perceived benefits. A longitudinal approach on the firm's needs is also welcome as the perceived value of science parks might change over time (Díez-Vial and Fernández-Olmos, 2017).

This thesis revealed that science parks are quite complex with different attributes serving different ends for different tenant firms. The common approach to prove the policy effectiveness of science parks is to include a firm characteristic which indicates if the tenant firm is located on or not located on a science park. The evidence suggests that this 'science park location' characteristic should be expanded in future evaluation research with at least variables concerning the local university, present research institutes and science park management function. These variables were perceived to be relatively important among the considered science park attributes. Hence, future research is needed for evaluating the actual performance of science park tenant firms. This thesis provides insight for selecting similar tenant firms for future evaluation research, which might circumvent some heterogeneity issues among sampled firms. Additional research on the different roles that tenant types serve could contribute to the further conceptualisation of science parks. Moreover, future research might consider other science park user groups besides tenant firms. For instance, the attributes that contribute to entrepreneurial activity among students could be an interesting research line in order to improve business activity on universities. The added value of science parks could also be studied on another level, through their effectiveness on the performance of knowledge workers on science parks, such as researchers, engineers and other specialists. On this level, more attention can be given to other proximity dimensions, such as social, cognitive and organisational proximity between knowledge workers.

Within the thesis, the classification of tenant types is part of an exploratory study in the Netherlands with a higher purpose of seeking the associations tenant firms make among attributes and benefits. Therefore, future research with larger samples of firms and even in other countries could provide for additional insights in tenant types and perceived associations. Similarly, additional stated choice experiments on location choice of technology-based firms are highly recommended. Larger sample sizes would allow for distinguishing classes among decision-makers based on their latent preferences (Hensher et al., 2015). This could further expand the knowledge on the motivations of the technology-based firms and provide for policy implications. In addition, this thesis could only reveal some aspects of the demand-side of science parks from the perspective of real estate management. More research is required to further explore the needs of tenant firms as specific design principles remain unknown, such as type of buildings or optimum dimensions of science parks in order to induce desired benefits. For real estate categories related to science parks, such as business parks, the demand-driven research approach could be of interest. This thesis lays the initial methodological groundwork for the classification of parks and tenant types, and the association analysis of perceived benefits and business park attributes. The understanding of important perceived benefits and the means to achieve these ends might contribute to more effective work environments. As a result of some similarities between science parks and business parks, future research on the latter could provide for additional insight for the former.

As mentioned in the research design this science park study focuses on the 'inner environment', which are the firms located within the boundary of the science park. Future research on science parks should consider the 'outer environment' through the respective regional and national innovation systems. In addition, with the recent revived attention towards business/knowledge ecosystems (Moore, 1993; Iansiti and Levien, 2004; Van Der Borgh et al., 2012; Clarysse et al., 2014) future research can explore the role of the science park within this larger scale.

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PART V

Curriculum Vitae
Publication List

Curriculum Vitae

Wei Keat Benny Ng was born on March 23rd 1988 in Eindhoven, the Netherlands. He studied the master Architecture, Building and Planning at the Eindhoven University of Technology. In 2015 he graduated within the Real Estate Management and Development group on possible solutions for the oversupply of industrial land within the Eindhoven region through inter-municipal collaborations. After his graduation he worked as a consultant at The Bridge Business Innovators, in which he learned the craft of new business development and innovation management.

From January 2016, Benny started his PhD studies at the Department of the Built Environment at Eindhoven University of Technology of which the results are presented in this dissertation. During this PhD he focused on the needs of tenant firms with regard to science park attributes. Benny has presented his work on various international conferences and his research has been published in leading peer-reviewed journals, such as Research Policy and The Journal of Technology Transfer. He has acted as reviewer for Journal of Corporate Real Estate, Research Policy and International Journal of Technoentrepreneurship. During his PhD studies Benny has supervised Built Environment students on both Bachelor and Master level and he has been invited by companies as guest speaker on his research topic. His research interests include behaviour of firms, innovation management and real estate management. From January 2020, Benny will join the research team of a.s.r. real estate, where he will continue his research activities in order to provide insight on real estate investment decision-making.

Publication List

Journal papers (published)

Ng, W. K. B., Appel - Meulenbroek, H. A. J. A., Cloodt, M. M. A. H. and Arentze, T. A. (2019). Towards a Segmentation of Science Parks: A Typology Study on Science Parks in Europe. *Research Policy*, 48(3), 719–732. https://doi.org/10.1016/j.respol.2018.11.004.

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Ng, W. K. B., Appel - Meulenbroek, H. A. J. A., Cloodt, M. M. A. H. and Arentze, T. A. (Submitted). Perceptual Measures of Science Parks: Tenant Firms' Associations between Science Park Attributes and Benefits.

Ng, W. K. B., Appel - Meulenbroek, H. A. J. A., Cloodt, M. M. A. H. and Arentze, T. A. (Submitted). Analysing Science Park Location Choice: A Stated Choice Experiment among Technology-Based Firms.

Conference contributions

Ng, W. K. B., Appel - Meulenbroek, H. A. J. A., Cloodt, M. M. A. H. and Arentze, T. A. (2017). Campus, Technopole, Science, Technology or Research Park: A Typology Study Science parks in Europe. Conference presentation *24th European Real Estate Society 2017* – Delft University of Technology.

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“只要你心誠志堅，念念回首處，既是靈山”

“Nothing in this world is difficult, but thinking makes it seem so.
Where there is true will, there is always a way.”

吳承恩

Wu Cheng’en

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Demand-driven Science Parks

The Perceived Benefits and Trade-offs of Tenant Firms with regard to Science Park Attributes

One of the innovation policies to stimulate technology development are science parks, area developments where technology-based tenant firms and knowledge-based institutions co-locate. Although science parks are established globally for decades, there is limited research into possible types within these real estate objects. Furthermore, the perceived benefits and trade-offs of tenant firms regarding what science parks offer have not been made clear yet. As science parks are locations that offer a mix of such facilities and services to a wide range of tenant firms, they can be configured in numerous ways.

The main research question is: *"Which types of science parks can be distinguished and what are the perceived benefits and trade-offs of science park tenant firms with regard to important science park attributes?"*

This PhD research aims to investigate the supply and demand-side of science parks in order to provide input for the development and management of science parks that fit the needs of the different tenant firms. Data is collected through four different studies. Overall the results from this PhD research provide insights in what science parks are, what they mean for tenant firms and which quality levels of important attributes would be chosen if tenants would be given science park alternatives.

DEPARTMENT OF THE BUILT ENVIRONMENT

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