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Contribution of Certain Enablers to Success Criteria of Science and Technology Parks

Csilla Toth[1], Beata Fehervolgyi[2], Zoltan Kovacs[2], Andras Hary[1*]

[1] ZalaZONE Tudományos Park Kft., Dr. Michelberger Pál út 3., H-8900 Zalaegerszeg, Hungary
[2] Faculty of Business and Economics, University of Pannonia, Egyetem u. 10., H-8200 Veszprém, Hungary
* Corresponding author, e-mail: andras.hary@apnb.hu

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Abstract

The paper aims to cover a research gap in the analysis of certain enablers and their role in the success of science and technology parks (STPs). The goal of the research was to analyse the features of the enablers and point out their potential relationships with various success criteria. The outcomes of the research will help park management better understand STP behaviours. The analysis was done based on the survey data of 113 STPs. After definitions of enabler areas and success criteria plus a literature review, first the interrelations of enabler elements have been analysed using the Association Rule Mining method. Then, their relationship towards eight success criteria measurements have been studied using statistical analysis in order to find the key success drivers. Such a combination has rarely been used for analysing STPs in related research. According to the findings, there are apparent patterns and features within the analysed enabler areas. This is unique feature of the current paper, which highlights the necessity of taking a complex approach towards park services. It underlines the need for research, development and innovation competences and structures in STPs. The statistically relevant enablers as success drivers have revealed the importance of the presence of several factors (like management behaviour, park activities, service elements, etc.). This underlines that balanced development is crucial to successful parks achieving high-level performance.

Keywords

science park, technology park, success factors, success criteria, park performance measurement

1 Introduction

Science and technology parks (STPs) can be found all over the world and offer an operating environment for many outstanding companies and research institutes, contributing to the economic development of the region concerned. The first parks appeared in the 1950s, then these initiatives really spread in the 1980s. Over the past decades, STP activity has been nearly doubled worldwide (Lecluyse et al., 2019). There are economic uncertainties that have led companies to develop strategies such as exiting the industry completely or, in extreme cases, reorganising operations (Mallinguh and Zéman, 2020) Therefore, it is beneficial for companies to operate in a park, as cooperation with other players can lead to mutual benefits. As special innovation ecosystems, they provide value not only to established actors, but also to their immediate and wider economic environment (Albahari et al., 2019; Bigliardi et al., 2006; Hobbs et al., 2017; Link and Scott, 2003). This kind of connection between the market activities of industrial and economic operators and the actors of the scientific and research economy is of paramount importance nowadays. Supply chain collaboration also has a positive impact on the competitiveness of SMEs along the supply chain (Cigolini et al., 2004). Definitions of supply chains use two different interpretations: one school of thought approaches the chain as a group of organisations and the other views it as a complex process (Gelei, 2010; Gelei and Dobos, 2014). Modern STPs are seen as a network-based structure that supports the development of a knowledge-based economy, while at the same time strengthening innovation capabilities (Albahari et al., 2018; Ng et al., 2021; van Geenhuizen et al., 2012).

The terminology of STPs for research purposes is not uniform. Both Löfsten and Lindelöf (2005) pointed out that there is no universally accepted definition of science in the field, so many similar terms are used to describe it, such as science park, research park, technology park, business park, innovation centre, etc. Earlier literature (see, for example,

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papers of Currie (1985), Eul (1985), MacDonald (1987), Monck et al. (1988)) tried to distinguish between innovation centres, science parks and technology parks, but from today's literature, Granstrand and Holgersson (2020) provide detailed definitions. Literature sources usually use the word "park" to describe a "place" that:

1. is primarily a property-based initiative, since it is tied to a specific location where the development of settled actors is possible,
2. an environment that provides high-quality units in a comfortable environment for conducting high added value (and related research, development and innovation) activities.

In this paper, we consistently use the term Science and Technology Park (STP), in line with the International Association of Science Parks and Areas for Innovation (IASP) definition:

"*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*" (IASP, online).

The aim of this paper is to present the results of the authors' research related to the topic, along with certain influencing factors of the success of STPs. Many aspects of parks are examined in the literature, one of the most thorough presentations of relevant research areas is given by the work of Albahari et al. (2023). A lot of research is devoted to comparing operations inside and outside the park, examining the advantages from the point of view of the actors settled in the parks. Many researchers touch on certain elements of park operation (role of universities, incubation activities, cooperation, etc.), but the scope of research examining parks at a systemic level is very rare. This is also true for analysing park performance, there are many publications on the factors of park success, but it is rare to analyse them as a whole. This is precisely the main contribution of the present research to the scientific discussions carried out in this area, intending to make findings by examining the success of parks together with certain characteristics influencing them. To this end, it seeks to explore the whole of the endowment areas, their internal characteristics and their relationships related to success.

Fig. 1 shows the subject and focus of the research. The study focuses on the range of services offered by STPs. This is complemented on the one hand by the characteristics related to management (management services, park activity elements such as incubation, research and development, etc.), on the other hand by knowledge-based services, including university connections. These areas are not always sharply distinguishable, and there is a close relation between them, in line with the definition of STPs.

2 Literature overview

The main role of STPs is therefore to provide space for economic, innovative and cooperative networking areas and activities. At the same time, in addition to the innovation role, the role of parks in establishing research and development culture and incubation through the regional and spillover effect is also highly significant. Related management research deals extensively with the issue of performance measurement. The current paper uses the concept of success as an analogy to performance itself, which is examined directly in the form of success criteria and then subdivided into enablers contributing to success. This terminology fits to performance management based on cause-and-effect relationships in management. The use of these concepts can be adapted from project management (see the writings of Cserháti and Szabó (2014); Lamprou and Vagiona (2022); Shokri-Ghasabeh and Kavousi-Chabok (2009); Ton et al. (2024); Westerveld (2003)). The terminology of enablers is very commonly found in excellence management (EFQM) and knowledge-based management (Lee and Choi, 2003; Magnier-Watanabe et al., 2011; Usman et al., 2021).

Based on this, the main success criteria (CSC) are the metrics by which the performance of the STP can be judged. In this regard, success criteria are the highest-level metrics related to the particular park mission, stakeholder satisfaction and expectations. Enablers are components leading to the achievement of the main goals and contributing to success.

This type of causal relationship forms the approach of the present research, with the limitation that the analysis examines the areas of enablers related to the subject of

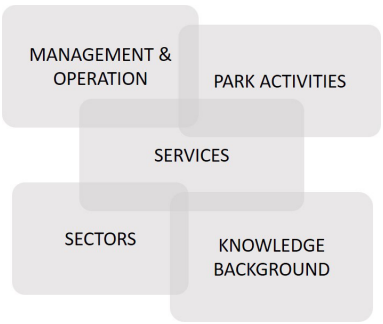

Fig. 1 Subject of research

the present research. The aim of the analysis is to provide a methodology for this processing, based on which further areas of enablers can be involved in future research.

When measuring the performance of STPs, research examining the performance of established actors, evaluating the regional impact of parks, analysing the performance of park management and analysing the park as a whole should be separated. The present research examines the topic at the level of the park as an innovation ecosystem, including the activities of management. In this regard, the work of Bigliardi et al. (2006) can be highlighted, which formulated number of indicators related to the measurement of management performance and the measurement of economic outcomes for the total number of settled organisations. The paper of Albahari et al. (2013) is partly in line with this, but it provides very detailed aspects related to the measurement of R&D activity. The study of Guadix et al. (2016) builds on these findings itself, proposing similar forms of measurement indicators, which can be regarded as a kind of summative work. Berbegal-Mirabent et al. (2020) are slightly more focused, building on six main indicators, while Dabrowska and Ferreira de Faria (2020) give very detailed list of measurement options, but mainly at the level of companies. The review of Entringer and da Silva (2020) is very detailed, highlighting the possibilities of park management, measuring park services. The works of Esmaeelzadeh et al. (2021) and Khanmirzaee et al. (2022), which examine interorganisational factors, shift the focus to some extent away from individual companies to the evaluation of parks as systems, but provide less concrete measurement guidelines. Ng et al. (2021) evaluate the role of geographic location in the success of parks and detail property characteristics. The research touches on the scope of capabilities through attributes, but does this less for measurement purposes, approaching the matter overall more descriptively. Liberati et al. (2016) is one of the works that examine in detail the role and importance of the sectoral specificities of park. The works of Gyurkovics et al. (2014), Xie et al. (2018), Albahari (2019) should also be highlighted, whose conclusions largely align with the previously mentioned aspects.

As a result of conducting a literature review involving a detailed overview of related papers, the main aspects in connection to measuring the performance of parks are summarised in Table 1.

Based on the literature review, it seems that there are many works related to the measurement and evaluation of STP performance. At the same time, the assessment of cause-effect relationships is more limited, and is mostly related to case studies of certain parks. The present research, building on the related literature findings, seeks to take this further. On the one hand, the exploration of the internal characteristics of the examined enablers, and on the other hand, the comprehensive analysis of the relationships between the enablers and the success criteria are addressed. For the purpose of an in-depth examination, certain enabler areas and success criterion areas were further broken down, as shown in Table 2.

Table 1 Results of the literature review (own edited)

Related papers	Success cr.			Enabler areas				
	1	2	3	4	5	6	7	8
Bigliardi et al. (2006)	O	O		O		O		
Ratinho and Henriques (2010)			O	O			O	
Albahari et al. (2013)	O	O	O		O	O	O	
Guadix et al. (2016)	O	O	O	O	O		O	O
Berbegal-Mirabent et al. (2020)	O	O	O		O			
Dabrowska and Ferreira de Faria (2020)	O	O				O		
Entringer and da Silva (2020)	O							O
Ribeiro et al. (2021)	O	O	O	O		O		O
Esmaeelzadeh et al. (2021)					O	O	O	O
Li and Gou (2018)			O			O		
Albahari (2019)				O	O		O	O
Gyurkovics et al. (2014)			O		O	O		
Liberati et al. (2016)						O		O

1: Park economy; 2: R&D performance; 3: Incubation performance; 4: Management and operations; 5: Park activities; 6: Park services; 7: Role of universities; 8: Specifics of actors

3 Research goal and method

The subject of the research is to examine the characteristics influencing the success of STPs. One of the research objectives is to explore the internal characteristics and relationships of the enablers. The other research objective is to analyse the relationships between enablers and success criteria.

Hypotheses of the research (Fig. 2):

- H1: The features of STPs have observable internal characteristics.
- H2: There are demonstrable relationships between the enablers and success criteria of STPs, and the strength of these relationships can be determined.

Data were collected during the research along the characteristics defined on the basis of literature sources identifying eight success criteria. The sample group included

Table 2 After the literature overview: focus of the current research

Park enablers >>>	Park success criteria
Management and operation:	Park economy:
• Park management activities	1. Companies in-park
• Operation elements	2. Revenue in-park
Park activity:	3. Employment in-park
• Activities in the park	4. Sites of park
• Incubation activities	R&D performance:
Services:	5. R&D investments
• General services in the park	6. R&D employment
• Knowledge-based services	Incubation performance:
University connections:	7. Companies in incubators
• University relationships	8. No. of start-ups
Sectoral features:	
• Sectors in the park	

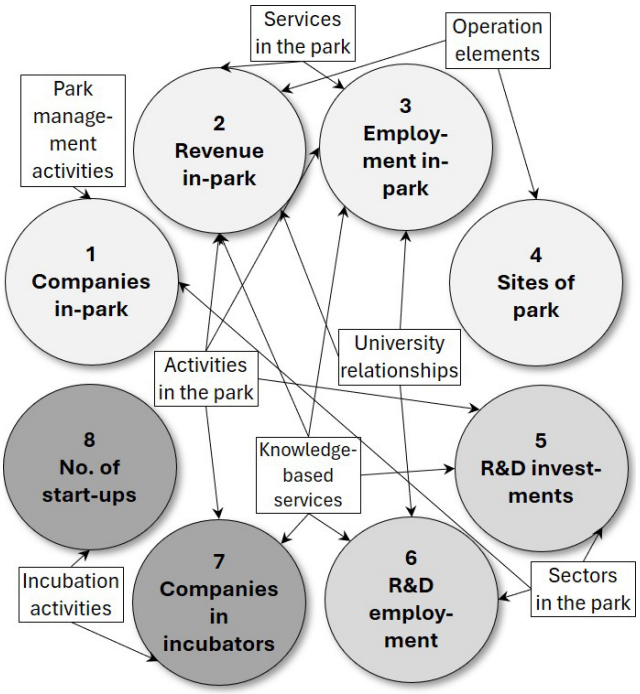

Fig. 2 Research hypotheses

113 STPs in the IASP network. The data was processed using statistical methods using Python, JAMOVI and R Studio software.

The elements of the eight enabler groups examined were assessed in the form of multiple-choice questions. In the first step, with the help of the Association Rule Mining analysis carried out within the enabler groups, the typical enabler-element characteristics were identified. The findings were discussed based on the result table of ARM run including support confidence and lift values for the most frequent items. Results have been visualised in graph charts. Subsequently, the most pronounced pairs of enabler elements were determined by means of a Kendall-tau relationship matrix. This matrix was created for each examined enabler area in order to identify the three highly ranked relation-pairs. Then the correlation of the enabler items and success criteria have been analysed by Fisher-exact test.

Fig. 3 shows the model of the research, the process from literature search through survey data to findings.

Based on the statistical analysis, it was shown:

1. the network relationship characteristics of certain groups of park features,
2. the identification of the defining enabler elements,
3. the range of characteristic enabler -success criterion relationships.

4 Results and findings

4.1 Analysis of the internal characteristics of park enablers

4.1.1 Park management activities

Based on the analysis of data from 111 parks, it appears that park management services related to business development play a central role. In addition, two additional nodes are the range of in-park communication and park event management services. They suggest the need for active management in the case of successful parks, for example fostering regular business development events for the actors of the park (Figs. 4 and 5).

4.1.2 Operation elements

Based on the analysis of data from 109 parks, the operational elements show a dense and integrated service portfolio. Social services are an absolute hub, connected to almost all other services. In addition, two groups can be highlighted: leisure activities and housing, and university and research institute presence. Incubation and acceleration are present a little further out, but in a similarly integrated form. This presents a diverse and interconnected service portfolio. Due to the importance of social

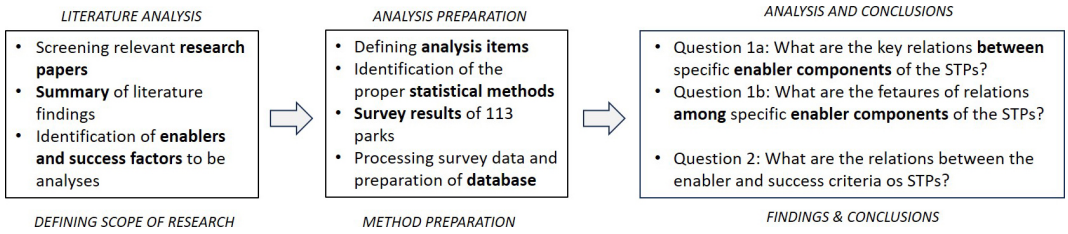

Fig. 3 Research model

	lhs	rhs	support	confidence	coverage	lift	count
[1]	{mgt_bd, mgt_ev}	=> {mgt_com}	0.60	0.84	0.72	1.1	67
[2]	{mgt_bd, mgt_com}	=> {mgt_ev}	0.60	0.84	0.72	1.1	67
[3]	{mgt_com}	=> {mgt_ev}	0.65	0.83	0.78	1.0	72
[4]	{mgt_ev}	=> {mgt_com}	0.65	0.82	0.79	1.0	72
[5]	{mgt_com, mgt_ev}	=> {mgt_bd}	0.60	0.93	0.65	1.0	67
[6]	{mgt_com}	=> {mgt_bd}	0.72	0.92	0.78	1.0	80
[7]	{mgt_bd}	=> {mgt_com}	0.72	0.79	0.91	1.0	80
[8]	{mgt_bd}	=> {mgt_ev}	0.72	0.79	0.91	1.0	80
[9]	{mgt_ev}	=> {mgt_bd}	0.72	0.91	0.79	1.0	80

Fig. 4 Results of ARM analysis – Park management activities

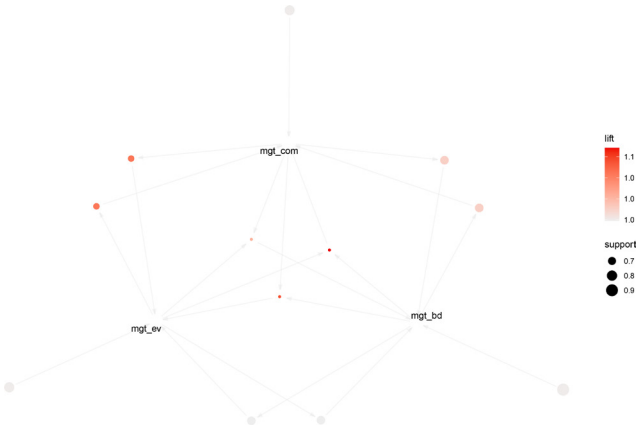

Fig. 5 Graph of ARM analysis – Park management activities

integration relevant platforms and events are crucial tools for the park management in the practice (Figs. 6 and 7).

4.1.3 Activities in the park

Based on the analysis of data from 109 parks, a marked central position of R&D and engineering services is clearly visible. Furthermore, consultancy activities and training and education as additional activities provide another relevant group of activities. It shows that, next to the R&D and innovation typical at STPs, the presence of related activities supporting them is also important for successful parks, like relevant start-up programmes or university competitions for trainees (Figs. 8 and 9).

4.1.4 Incubation activities

Based on the analysis of data from 109 parks, it appears that there is a significant connection between incubation activities and universities, R&D and acceleration activities. In addition, incubation activity appears as a characteristic of R&D institutions at the top of the association ranking. These connections can also be observed in the other direction. That is, the presence of universities, research institutes appear together with the number of organisations

	lhs	rhs	support	confidence	coverage	lift	count
[1]	{hous_appart, leisure_act}	=> {social_serv}	0.31	0.94	0.33	1.7	34
[2]	{house_appart, leisure_act, r_d_instit}	=> {social_serv}	0.30	0.94	0.32	1.7	33
[3]	{house_appart, r_d_instit}	=> {social_serv}	0.30	0.89	0.34	1.6	33
[4]	{house_appart}	=> {social_serv}	0.32	0.88	0.37	1.5	35
[5]	{accelerator, incubator, leisure_act, r_d_instit, university}	=> {social_serv}	0.37	0.87	0.42	1.5	40
[6]	{house_appart, incubator}	=> {social_serv}	0.30	0.87	0.35	1.5	33
[7]	{accelerator, leisure_act, r_d_instit, university}	=> {social_serv}	0.37	0.85	0.43	1.5	40
[8]	{accelerator, incubator, leisure_act, university}	=> {social_serv}	0.37	0.85	0.43	1.5	40
[9]	{incubator, leisure_act, r_d_instit, university}	=> {social_serv}	0.41	0.85	0.49	1.5	45
[10]	{leisure_act, r_d_instit, university}	=> {social_serv}	0.43	0.84	0.51	1.5	47

Fig. 6 Results of ARM analysis – Operation elements

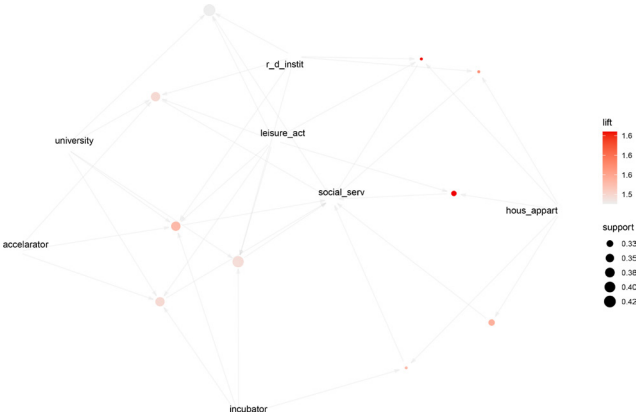

Fig. 7 Graph of ARM analysis – Operation elements

	lhs	rhs	support	confidence	coverage	lift	count
[1]	{consult2, r_d}	=> {engineer}	0.43	0.85	0.50	1.2	47
[2]	{consult2, r_d}	=> {train_educ}	0.47	0.93	0.50	1.2	51
[3]	{consult2}	=> {train_educ}	0.51	0.92	0.56	1.2	56
[4]	{manufact, train_educ}	=> {r_d}	0.41	1.00	0.41	1.1	45
[5]	{engineer, train_educ}	=> {r_d}	0.58	1.00	0.58	1.1	63
[6]	{consult2, engineer}	=> {r_d}	0.43	0.98	0.44	1.1	47
[7]	{engineer}	=> {r_d}	0.71	0.97	0.72	1.1	77
[8]	{manufact}	=> {r_d}	0.51	0.97	0.53	1.0	56
[9]	{engineer, manufact}	=> {r_d}	0.41	0.96	0.43	1.0	45
[10]	{train_educ}	=> {r_d}	0.73	0.93	0.79	1.0	80

Fig. 8 Results of ARM analysis – Activities in the park

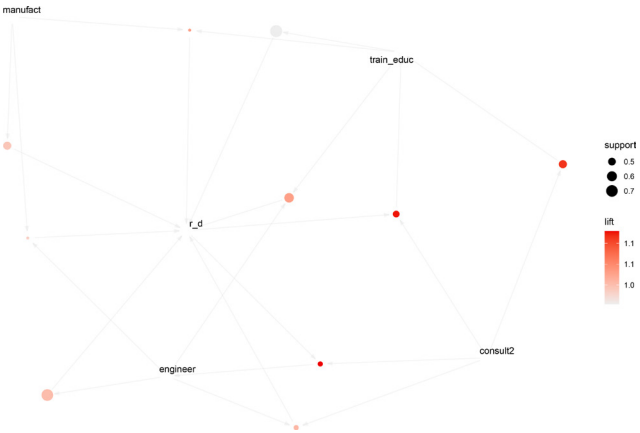

Fig. 9 Graph of ARM analysis – Activities in the park

incubated. Practical start-up and spin-off programmes are supportive to this kind of activity (Figs. 10 and 11).

4.1.5 Services in the park

Based on the analysis of 107 parks, it can be seen that the range of services is diverse and present in large quantities in the parks. Innovation spaces can be found for the most part, similarly important is the relationship of IT and related services with security services. The other key area is connecting actors and the area of the rooms available for rent. Facility investment programmes should consider this (Figs. 12 and 13).

4.1.6 Knowledge-based services

According to the analysis of 109 parks, the range of knowledge-based services is diverse, mainly business and competency-based services come to the fore, but financial areas, technology-related matters and sales are also important central elements. Sales and networking activities are clearly one of the most important areas in the practice to which many other services are connected. Furthermore, there is a centralisation around technological areas, showing connection with the other elements (Figs. 14 and 15).

	lhs	rhs	support	confidence	coverage	lift	count
[1]	{accelarator, university}	=> {r_d_instit}	0.57	0.94	0.61	1.2	62
[2]	{accelarator, incubator, university}	=> {r_d_instit}	0.56	0.94	0.60	1.2	61
[3]	{incubator, university}	=> {r_d_instit}	0.66	0.91	0.72	1.1	72
[4]	{university}	=> {r_d_instit}	0.69	0.90	0.76	1.1	75
[5]	{accelarator, university}	=> {incubator}	0.60	0.98	0.61	1.1	65
[6]	{accelarator, r_d_instit, university}	=> {incubator}	0.56	0.98	0.57	1.1	61
[7]	{accelarator, r_d_instit}	=> {incubator}	0.64	0.97	0.66	1.0	70
[8]	{r_d_instit, university}	=> {incubator}	0.66	0.96	0.69	1.0	72
[9]	{accelarator}	=> {incubator}	0.77	0.95	0.81	1.0	84
[10]	{r_d_instit}	=> {incubator}	0.77	0.95	0.81	1.0	84

Fig. 10 Results of ARM analysis – Incubation activities

Fig. 11 Graph of ARM analysis – Incubation activities

	lhs	rhs	support	confidence	coverage	lift	count
[1]	{connection, innov_places, security_s}	=> {it_and_technol}	0.64	0.99	0.64	1.1	68
[2]	{connection, innov_places, restaur, security_s}	=> {it_and_technol}	0.63	0.99	0.64	1.1	67
[3]	{connection, innov_places, rooms, security_s}	=> {it_and_technol}	0.63	0.99	0.64	1.1	67
[4]	{connection, innov_places, restaur, rooms, security_s}	=> {it_and_technol}	0.62	0.99	0.63	1.1	66
[5]	{innov_places, security_s}	=> {it_and_technol}	0.79	0.98	0.81	1.1	85
[6]	{innov_places, rooms, security_s}	=> {it_and_technol}	0.79	0.98	0.80	1.1	84
[7]	{innov_places, restaur, security_s}	=> {it_and_technol}	0.76	0.98	0.78	1.1	81
[8]	{innov_places, restaur, rooms, security_s}	=> {it_and_technol}	0.75	0.98	0.77	1.1	80
[9]	{connection, securirty_s}	=> {it_and_technol}	0.64	0.97	0.66	1.1	69
[10]	{connection, restaur, security_s}	=> {it_and_technol}	0.64	0.97	0.65	1.1	68

Fig. 12 Results of ARM analysis – Services in the park

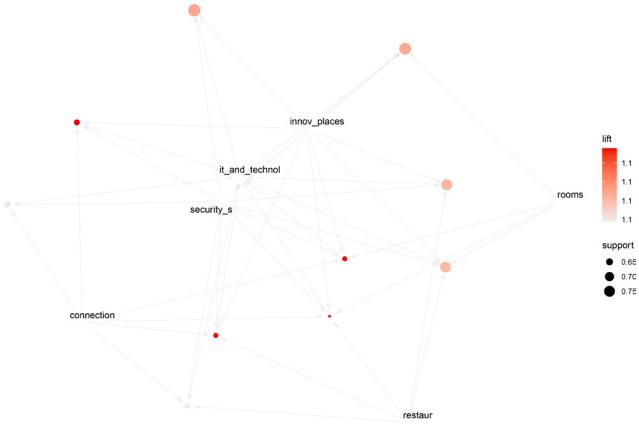

Fig. 13 Graph of ARM analysis – Services in the park

4.1.7 University relationships

Based on the analysis of data from 63 parks, it can be concluded that university appearance is one of the most important integrating factors in STPs. The presence of research groups definitely stands out, many other forms are associated with this. Further activities are likely to build on this, and this is the subject of further research. In addition, cooperation and agreements between the park and universities form an independently emerging hub. In other words, the integration of universities into STPs is very important in the practice, at all stages starting from the first physical appearance through concrete projects to a larger-scale presence. This activity should be key element of park development plans (Figs. 16 and 17).

4.1.8 Sectors in the park

Based on the analysis of 110 parks, the service sector and the industrial sector are the most centralised, and this is where the main focus of parks can be observed. There is also an aggregation in food and agriculture and aero technology and natural sciences. ICT and biochemistry have less strong relations. Most of the parks are active in these

	lhs	rhs	support	confidence	coverage	lift	count
[1]	{financing, technol}	=> {sales_netw}	0.66	0.99	0.64	1	72
[2]	{competence, financing, technol}	=> {sales_netw}	0.66	0.99	0.64	1	72
[3]	{business, financing, technol}	=> {sales_netw}	0.65	0.99	0.64	1	71
[4]	{business, competence, financing, technol}	=> {sales_netw}	0.65	0.99	0.63	1	71
[5]	{financing}	=> {sales_netw}	0.78	0.98	0.81	1	85
[6]	{competence, financing}	=> {sales_netw}	0.78	0.98	0.80	1	85
[7]	{business, financing}	=> {sales_netw}	0.77	0.98	0.78	1	84
[8]	{business, competence, financing}	=> {sales_netw}	0.77	0.98	0.77	1	84
[9]	{financing}	=> {competence}	0.80	1.00	0.66	1	87
[10]	{financing, technol}	=> {competence}	0.67	1.00	0.65	1	73

Fig. 14 Results of ARM analysis – Knowledge-based services

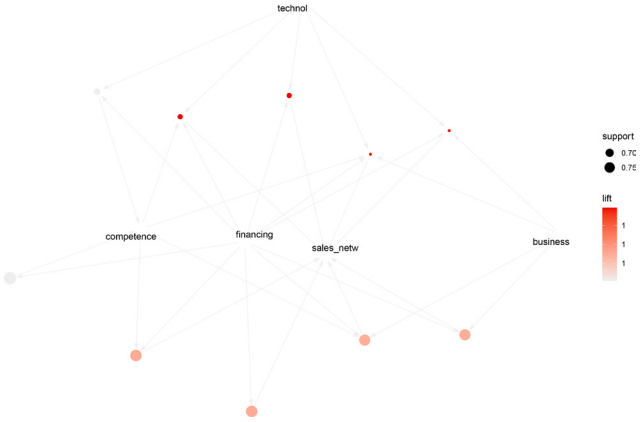

Fig. 15 Graph of ARM analysis – Knowledge-based services

	lhs	rhs	support	confidence	coverage	lift	count
[1]	{agreem, univ_ind_office}	=> {res_groups}	0.17	1.00	0.17	2.0	11
[2]	{agreem, services, univ_ind_office}	=> {res_groups}	0.16	1.00	0.16	2.0	10
[3]	{agreem, labs, univ_ind_office}	=> {res_groups}	0.16	1.00	0.16	2.0	10
[4]	{agreem, labs, services, univ_ind_office}	=> {res_groups}	0.14	1.00	0.14	2.0	9
[5]	{univ_ind_office}	=> {res_groups}	0.17	0.92	0.19	1.8	11
[6]	{services, univ_ind_office}	=> {res_groups}	0.16	0.91	0.17	1.8	10
[7]	{labs, univ_ind_office}	=> {res_groups}	0.16	0.91	0.17	1.8	10
[8]	{labs, services, univ_ind_office}	=> {res_groups}	0.14	0.90	0.16	1.8	9
[9]	{univ_ind_office}	=> {services}	0.17	0.92	0.19	1.6	11
[10]	{univ_ind_office}	=> {labs}	0.17	0.92	0.19	1.6	11

Fig. 16 Results of ARM analysis – University relationships

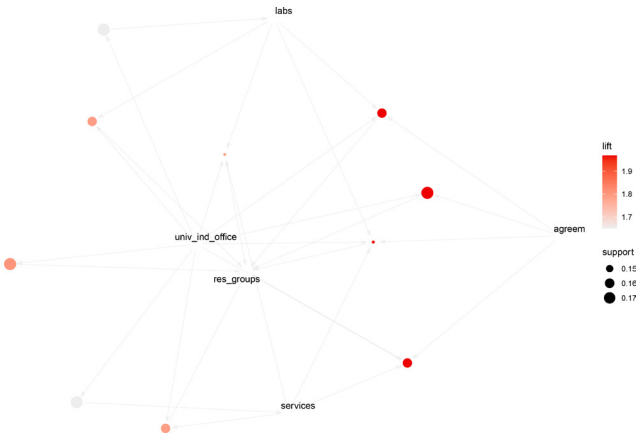

Fig. 17 Graph of ARM analysis – University relationships

sectors, and to a lesser extent they specialise in one of the sectors mentioned above (Figs. 18 and 19).

4.2 Internal relationships of the elements of park facilities

Building on Table 2 measurement categories, relationship matrices have been created. The statistical examination was based on the ranking-based Kendall-tau study analysis of the data. An example is shown in Fig. 20.

Such a matrix has been prepared for each of the eight enabler areas examined, which clearly shows which enabler-element pairs are more present in the operation of parks. From this it can be concluded which are the most pronounced pairs of enablers and elements that significantly contribute to the success of the park. It should be noted that it is not the absolute statistically proven relationship that is relevant in the present study, but rather the contextual

	lhs	rhs	support	confidence	coverage	lift	count
[1]	{aero_space, food_agricult_social_areas}	=> {natural_science}	0.18	0.91	0.20	1.4	20
[2]	{aero_space, food_agricult_service, social_areas}	=> {natural_science}	0.18	0.91	0.20	1.4	20
[3]	{aero_space, food_agricult_ict, social_areas}	=> {natural_science}	0.18	0.91	0.20	1.4	20
[4]	{aero_space, food_agricult_ict, service, social_areas}	=> {natural_science}	0.18	0.91	0.20	1.4	20
[5]	{aero_space, food_agricult_industry, social_areas}	=> {natural_science}	0.17	0.90	0.19	1.3	19
[6]	{aero_space, food_agricult_industry, service, social_areas}	=> {natural_science}	0.17	0.90	0.19	1.3	19
[7]	{aero_space, food_agricult_ict, industry, social_areas}	=> {natural_science}	0.17	0.90	0.19	1.3	19
[8]	{aero_space, food_agricult_ict, industry, service, social_areas}	=> {natural_science}	0.17	0.90	0.19	1.3	19
[9]	{aero_space, bio_chem, food_agricult, social_areas}	=> {natural_science}	0.16	0.90	0.18	1.3	18
[10]	{aero_space, bio_chem, food_agricult, service, social_areas}	=> {natural_science}	0.16	0.90	0.18	1.3	18

Fig. 18 Results of ARM analysis – Sectors in the park

Fig. 19 Graph of ARM analysis – Sectors in the park

	labs	services	research_groups	univ_office_in_park	agreements	occassional
labs	---					
services	0.581	---				
research_groups	0.341	0.303	---			
univ_office_in_park	0.271	0.271	0.343	---		
agreements	0.187	0.131	0.053	-0.117	---	
occassional	-0.025	-0.025	0.127	0.074	-0.283	---

Fig. 20 Kendall relationship matrix (example)

ranking of enabler factors. Selecting the strongest pairs of relations, there were determined three pairs of such marked elements that are most characteristic of each enabler. This is shown in Table 3, the role of which is that working with these pairs of elements considered during the analysis as the most relevant factors for management decisions.

4.3 Internal relationships of the elements of park facilities

In order to examine the relationship between the eight enabler areas and the success criteria, the most important pairs of elements have been identified. During the study, the relationship of their presence with the metric of the related success criterion has been analysed. The purpose of this is to draw conclusions on the extent to which the different park success criteria are influenced by the presence of these marked feature pairs in parks.

For the study, the relationship between the selected enabler areas and the success criteria was examined using the Fisher exact test, see the relationship lines shown in Fig. 2. From the point of view of capabilities, the most important pairs of elements listed in Table 3 were used for the analysis as one side elements of the relationship to be validated. Accordingly, the results include three statistical indicators as shown in Fig. 21.

Based on Fig. 21, it can be determined which are closer and less close relationships. The analysis showed that eight stronger links can be identified, indicated by thicker lines, which can be linked to the number of settled companies, park employment, park revenue, R&D investment and employment criteria. Other connections considered less strong can be investigated in more depth in further research and with the inclusion of further enabler aspects.

Table 3 The most strongly related park feature pairs

Enabler	Enabler item pairs	Kendall relationship index
Management activities	Strategic mgt+financial planning	0.523
	Service development+events	0.482
	Financial planning+contacts	0.430
Operation elements	Leisure act.+social serv.	0.566
	Social serv.+house appart.	0.471
	Universities+R&D institutes	0.436
Activities in the park	Engineering+R&D	0.386
	Consulting+training, education	0.330
	Consulting+sales	0.266
Incubation activities	Universities+R&D Institutes	0.444
	Universities+incubator	0.180
	R&D Institutes+Incubator	0.130
General services in the park	mtg.room+conf.room	0.601
	Secur.surveillance24h+mtg.room	0.468
	Secur.service+connect 5G	0.465
Knowledge-based services	Investor conn.+partnerships	0.556
	Investor conn.+fund assist	0.442
	Fund assist+mentoring	0.441
University relationships	Labs+services	0.581
	Univ_office_in_park+labs	0.343
	Research groups+labs	0.341
Sectors in the park	Software (SW)+Artificial Intelligence (AI)	0.695
	SW+communication	0.562
	Electronics+communication	0.530

5 Conclusions

The aim of the research was to examine the relationships between the characteristics and success criteria of STPs. Following a literature review, based on the data of surveys of 113 international STPs, first the characteristics were analysed and then the link to the success criteria was evaluated.

The analysis carried out in eight areas of the conditions using the Association Rule Mining method yielded a number of novel conclusions. It can be concluded that successful parks require active management activities. This shows the proactive and intensive communication and presence of the management towards those who settled in the parks. In addition, it has been explained that the service portfolio of STPs is diversified and no single typical pattern can be

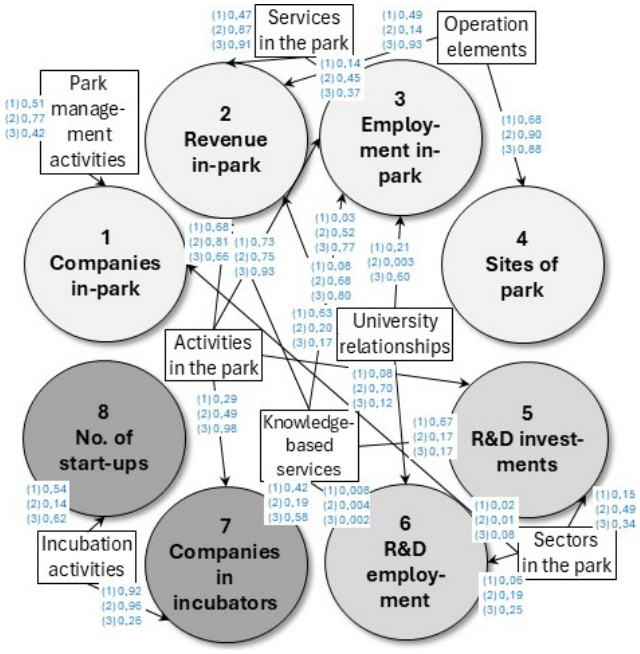

Fig. 21 Results of relationship analysis (Fisher exact tests, based on *p*-values)

established. At the same time, service elements are present in a mutually reinforcing way, many combinations of individual services can be found in the practice of parks. These often include related relationships (e.g., university and R&D services, services of a social nature, etc.). It is also important to note that it is complemented by related activities supporting research, development and innovation activities. Since research and development is a natural feature of STPs, it is shown among the activities at each park. The integration of universities into parks is an evolutionary process with many stages of development and many forms. However no typical, widespread form can be detected, but there are many different modes of university presence and their many combinations. The ARM study showed the connections and central elements of the various enablers. The services are clearly diverse, while the incubation activity is narrower and the parts of these operate independently.

According to the paired relationship analysis carried out for the endowment elements in order to examine the relationship between the characteristics and the success criteria of the park, social and R&D operational elements are almost always present together in parks. In addition, it can be stated that the investor and financial aspect is of paramount importance among services, which is certainly important in connection with the start-up and incubation activities of parks. The analysis also showed that related sectors such as software development, artificial intelligence and communication technologies are very often present, but the same is true for traditional industrial sectors.

The relationship analysis yielded demonstrable results from traditional park development criteria (number of settled organisations, park turnover and employment) and R&D criteria (R&D investments and employment). As a result, eight main endowment connections were identified; confirming the importance of the examined areas for the success of parks: traditional and knowledge-based services, park activities, university relations, and the role played by sectors.

The activities of park management, as well as incubation activities and the connection with start-up results require further research. The present work, with the methods and survey criteria used here, did not focus on deeper exploration of this topic, which is no less important from the point of view of STPs.

Thus, the results of the present research have confirmed the relationship between the success criteria and enablers of the park, as measures of success and the internal characteristics supporting them. It can also be seen from the analysis that strength of the relationship differs significantly in the various areas, providing further research opportunities for the topic.

Although the examined parks are internationally well diversified, there are still some limitations to the analysis. The paper focused on eight success criteria but future research could involve the evaluation of further aspects. The methods used in this study essentially concluded findings on relationships or associations but did not address cause and effect relations. Such causal features can be the subject of future research.

Nevertheless, the present research contributes towards better understanding of the behaviour and the developmental characteristics of STPs in a way that has not been studied before.

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