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Method for Assessment of Characteristics of European Innovation Ecosystems

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The aim of the research is to investigate if certain characteristics (the sectoral focus of innovation ecosystems, the breadth of park functions, the position of human vs. technological focus, the presence of cooperation (commercial vs. research economy), the prosperity and success of the park, and the characteristics of park management) can be applied to evaluate innovation ecosystems, through the example of European science parks surveyed.
Study Design: Innovation ecosystems are important catalysts for R&D and innovation activities. In today's significantly changing technological environment, collaborative systems that can also contribute to the strengthening of high added value activities are of particular importance. Although innovation ecosystems have a long history, some aspects of the current R&D challenges need to be revisited. Research on the subject suggests that the innovation ecosystem is not an absolute concept, as in practice it takes many different forms. These ecosystems also offer a research

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framework whether the industry actually follows an interdisciplinary and academic trend on the formation of knowledge and its value within the industry itself. In fact, it is knowledge that develops people, or people who build this knowledge over time, in a participatory way. Therefore, the nature, structure and functioning of a given ecosystem depends on a number of factors; it can take different forms, depending on the specific regions, industries, cooperation systems and cultures.
Methodology: The concept and functioning of innovation ecosystems can be related to research on the characteristics of complex systems, based on previous research, and the research (questionnaire survey) therefore covers several topics of different nature. Members of the International Association of Science Parks and Areas of Innovation (IASP) participated in the survey. The analysis provides findings on the functioning of these characteristics and a comparison between innovation ecosystems. Finally, the authors make suggestions for possible future research directions and further work on the topic.
Results: The authors examined the sectoral focus of innovation ecosystems, the breadth of park functions, the position of human vs. technological focus, the presence of cooperation (commercial vs. research economy), the prosperity and success of the park, and the characteristics of park management by the survey of European science and technology parks. Based on discussing findings through these characteristics, the authors highlighted that these aspects and the methods of data processing can be used to point out features and differences of various science and technology parks.
Conclusion: The research has already focused on the classification of innovation ecosystems with different characteristics, and the present study builds on the related research findings, while focusing on the characteristics of the functioning of innovation ecosystems in Europe and the assessment of their interrelationships.

Keywords: Innovation ecosystem; science park; triple helix; sectoral focus; success factors.

1. INTRODUCTION

In recent years, there has been a growing interest in the concept of ecosystems as a framework of describing the innovation and business environment. The term came into a focus not only for high-tech firms, but also for regional and sectoral developments. Ecosystems are also often used in strategic areas, both in economic development and innovation systems, and the concept helps to conduct innovation-focused strategic analyses. Ecosystems do not fit into the classic supplier-customer relationship structure, nor can they be considered as merely a hierarchical system.

Differing from the concept of innovation systems, the term of innovation ecosystems has become very popular in related research, typically with a business and strategic origin and focus. This is a departure from the original policy and institutional focus that has dominated the innovation systems literature in the past. The understanding of the concept of innovation ecosystems thus varies from the previous conceptual approach to innovation systems. The intensified use of the concept of innovation ecosystems was accelerated after the publication of Adner's article [1], which provides probably one of the most widely used definition of innovation ecosystems. He defines innovation ecosystems as 'collaborative arrangements through which firms combine their offerings to deliver coherent, customer-oriented solutions'.

Jackson [2] conceptualized the innovation ecosystem as a system of complex relationships, and from his perspective, it is a field of actors or entities whose functional purpose is to facilitate or utilize technological development and innovation.

According to Carayannis and Campbell [3], the 21st century innovation ecosystem is a multi-level, multi-modal, multi-nodal and multi-agent system. Based on their research, the innovation architecture is composed of human, social, intellectual and financial capital, as well as cultural and technological enablers and modalities, constantly evolving and interacting together.

Still et al. [4], offer a thorough literature review, including definitions of innovation ecosystems. They look at innovation ecosystem as “entities composed of organizations and the relationships between them”. The authors underline that the human networks of innovation ecosystems generate high-level of creativity and innovative outputs. The sustainability of innovation

ecosystems is firmly influenced by the set of interdependent firms which are in symbiotic relationships with each other to produce and deliver new and innovative products and services.

Walrave et al. [5] offer a similar approach to the characterize the innovation ecosystems, as “a network of interdependent actors that combine specific yet complementary resources and/or capabilities to create and deliver a comprehensive value proposition to their end-users”.

Next to these referenced classic approaches, the complexity of the innovation ecosystem concept is also indicated by several of latest research, pointing out the complex feature of the different actors, the multi-variable nature of their cooperation, the specific activities and value creation characteristics of the ecosystem, whilst the role of co-development and co-evolution, the innovation-driven focus on results (output products and services), and the duality of competition and R&D are still relevant aspects. See works of Jucevicius and Grumadaite [6], Bonnici [7], Carmichael and Hadzikadic [8] in this topic.

2. LITERATURE REVIEW

The research shown in this paper is generated by the need for surveying differences and special characteristics of the innovation ecosystems. Therefore, the literature review below is mainly prepared to support this perspective.

The basic roots of the innovation ecosystem concept can be traced back to the related concept of business ecosystems as published by Moore [9] and other related authors from these times. These roots of the classic publications are basically derived from the usual value creation model which is the basis of a business approach.

According to the Westhead and Batstone [10] concept to innovation ecosystems a few years later, the resources needed to the research economy are related to the resources produced by the commercial economy. An important feature is that the actors of an ecosystem are either geographically localised or strategically interconnected so as to be focused around a particular technology area. This is one of the first paper which called the attention to the needed balance of the commercial and research economy at innovation ecosystems.

Nearly a decade later, work of Oh et al. [11] also detailed that that the innovation ecosystem can be linked to two distinct and separate economies, one is the research economy, driven by basic research, and the other is the commercial economy, driven by the market. The authors argue that the cooperation and relationships between these two economies define the basic feature of an innovation ecosystem, therefore the two aspects should be focus of the relevant research.

According to Granstrand and Holgersson [12], an innovation ecosystem is the set of actors, activities and products, as well as institutions and relationships, including complementary and substitute relationships, that are important for the innovative performance of actors. This paper deals with the dual role of activity and value creation positioning, such as questions of complementarity and opportunity for substitution.

An innovation ecosystem is therefore always a collection of different types of actors with different objectives and different operational characteristics. The operating culture of a research institution and the operating environment of a market-based company are completely different. For this reason, an innovation ecosystem can also be a bridge between the various actors. The differences of the actors form the conditions of the complementarity-based cooperations, but also pose management challenges. The analysis of the different innovation ecosystems shows that there is no single model, but that there are many different ways for designing the structure of an ecosystem. The actual structure and functioning of an innovation ecosystem depend on various factors, such as location, environment, form and conditions of establishment as well as the value proposition (why is it better to be involved into the ecosystem vs. remaining outside of it).

The conceptualization of science and innovation parks is linked to the theory of innovation ecosystems. The "Triple Helix" knowledge model, developed by Etzkowitz and Leydesdorff [13] emphasizes three so-called "helices" which are present in the innovation system: academia/universities, industry and state/government. The authors discuss the links and networks between these three players, with a particular emphasis on hybrid networks where each of the helices overlap. The model emphasizes the positive interactions among academia, government and industry, and

highlights the potential for joint action between the three types of stakeholders. In another related publication, Etzkowitz [14] refers to an 'entrepreneurial university' as a way of bringing academia and the market closer together. The effective connection of academic research and business-oriented R&D require the creation of 'entrepreneurial universities' and 'academic firms, as Campbell and Güttel [15] explained.

Etzkowitz and Klofsten [16] propose a knowledge-based regional development model as a practical application of the triple helix. This is a kind of conceptualization based on alternative technological paradigms, through a set of "multilinear dynamics". This case, the innovation effect is generated from the bottom-up as a result of “collective ventures”, realized through the collaboration of firms, governments and academics.

According to Leydesdorff et al. [17], economic growth depends not only on presence of innovation, but also on the structure of innovation, for example combining basic and applied research. While universities represent intellectual capital and are responsible for the creation of scientific knowledge, industries are responsible for the creation of economic outcomes and realization of corporate strategies. Public institutions, with their specific control and legal mechanisms, represent dominancy of regulations, policies, sectoral strategies and actions, views of decision-makers. These three different agents, actors can react to each other's actions while innovation systems evolve, require adjustments and adaptations in response to the respective actions.

Anbari and Umpleby [18] argued that one of the reasons for creating research networks is especially bringing together knowledge holders and practitioners throughout aligned complementary skills.

Based on conclusions of De Fuentes and Dutrénit [19], the interactions between the different stakeholders of the different helixes in the context of the used knowledge channels should be taken into account when analysing the geographical aspects of ecosystem interactions. This is particularly important due to the different nature of the knowledge flows involved, so relevant aspects should be analysed. Galvao et al. [20] also reviewed the research trends related to the triple-helix model and pointed out that one interpretation is to exploit the benefits from the different perspectives of each stakeholder.

Adopting the basic triple helix model, the scope of innovation ecosystems examined is defined accordingly, as shown in Table 1.

Table 1. Possible founding stakeholder groups of innovation ecosystems

Triple helix aspects	Actors
Government	Local (city) Region State
Academy/universities	Universiti(es)
Business/industry	Private person(s) Companies

Paper by Jacobides et al. [21] describes in detail three main orientations of ecosystems: the "business ecosystem", which focuses on a firm and its environment; the "innovation ecosystem", which is centred around a particular innovation or new value proposition and the actors that support it, and the "platform ecosystem", which takes into account how actors organize themselves around (for example, a technology) platform.

As Teece [22] explained, business ecosystems might focus not only a specific firm or new venture, but view the ecosystem as a community of organizations, institutions and individuals that impact on the firm(s) and its/their performance. His concept looks at the ecosystem as an economic community of interacting actors, all of which influence each other through their business activities. However, the actors involved are usually not from a single industry, therefore need for collaboration is there. In this approach, the ecosystem represents the environment that a company need to monitor and that influences its dynamic capabilities and thus, its ability to build sustainable competitive advantage utilizing benefits of the ecosystem. From this point of view, surveying the sectoral or technological focus is an important question. Beyond that, it is still a relevant feature if there is a central or focal firm controlling knowledge transfer, innovation appropriateness and network stability.

Within an innovation ecosystem, the interdependent actors should interact to create and commercialize innovations that deliver value for the end-customer. If coordination within an ecosystem is not adequate, innovations might fail; see Adner and Kapoor [23], Kapoor and Lee [24]. The innovation ecosystem concept is therefore not only about capturing the relationship between the core product, its components and complementary products/

services that altogether add value for customers, but also about management of the whole system, as subject of a required analysis.

Platform-based ecosystems are often organized around a technology platform. According to this approach, the ecosystem consists of the acting companies and complementary players who together create value for the end-customer. By joining the platform, complementary actors can not only generate additional innovation, but also might gain direct or indirect access to the platform's customers. This way, the platform-type ecosystems can be considered as "semi-regulated marketplaces" that encourage entrepreneurial actions under the coordination and guidance of a focal player Wareham et al. [25] or as "multilateral markets" that allow transactions between different user groups [26].

Katri [27] gives a very detailed overview on the different approaches to business, innovation and knowledge ecosystems, as three potential types (see Fig. 1). It is important to understand the different features of them, because the positioning and content realisation of an ecosystem is usually not based on a single model, but may carry different characteristics of different types of innovation ecosystems in the same time. According to research and findings of Katri, the three different types of economic ecosystems can be clearly distinguished. The literature on business ecosystems and service or industrial ecosystems emphasizes economic outcomes and business relationships between actors. The discussion of innovation (eco-) systems and regional clusters focuses on mechanisms and policies that foster the creation of innovative start-ups or clusters. The main interest and outcome of knowledge ecosystems is the creation of new knowledge through joint research work, collaboration or development of the knowledge base.

Gomes et al. [28] argue that the concept of innovation ecosystem was originally created as a response to the challenges of the earlier business ecosystem, which was dominantly focused on value accumulation and competitiveness, and that the concept of innovation ecosystem could place more emphasis on innovation-based, joint value creation and collaboration.

According to some researchers, the shift from the concept of business ecosystems to innovation ecosystems may have shifted the focus too much from competition to collaboration. Moreover, substitution of products and resources, including innovative technologies, is often out of the consequent definitions.

3. METHODS

Taking into account the theoretical considerations detailed above, and building on the authors' previous research, the authors distinguish five different types of innovation ecosystems in the present study. These types are also in line with the main elements of the innovation ecosystem model presented in previous publications of the authors, representing the possible functional areas of science and innovation parks. The different types of innovation ecosystems and their basic orientations are:

- Business park: dominated by market-based services, industrial and R&D activities,
- Innovation hub: dominated by SME-related activities and start-up services,
- Technology park: dominated by a technological or professional focus, knowledge background (local, industrial, scientific or innovation capabilities),
- University park: dominated by university presence and international research and education activities,
- General science park: all four characteristics listed above are present, in a balanced structure.

The inspiration of the current research is to point out whether specific and particular differences could be identified based on surveying of selected European science and technology parks, as high-performing innovation ecosystems.

The intention of the current research is to offer a preliminary, small-scale survey, with the intention to establish a large-scale survey while validating the key research directions in the same time.

The aim of the research is therefore, to investigate various features of innovation ecosystems: the sectoral focus, the breadth of park functions, the position of human vs. technological focus, the presence of cooperation (commercial vs. research economy), the prosperity and success of the park, characteristics of park management.

The concept and functioning of innovation ecosystems can be related to research on the characteristics of complex systems, based on previous research, and the research (questionnaire survey) therefore covers several topics of different nature.

The analysis provides findings on the functioning of these characteristics and a comparison between innovation ecosystems.

European members of the International Association of Science Parks and Areas of Innovation (IASP, www.iasp.ws) were addressed to join the survey. The mission of the IASP is to build a network of science parks and areas of innovation in Europe and worldwide to drive forward the growth potential of its members and help them to internationalize and increase their operational efficiency. The IASP coordinates the network of these parks on a single platform and is able to create new co-operation opportunities for its members (able to multiply global connections) by providing participation in international scene and thus developing innovation as a key characteristic of the parks.

The survey presented here examined data from 12 European innovation and science parks which were the respondent of the circulated survey questionnaire among a 45 park sample group.

In order to validate the original assumptions of this research, a questionnaire of 15 questions was sent to the pre-selected parks. The conclusions were drawn by qualitative processing and analysis of the responses received.

The innovation ecosystem approach leads to the conceptualization of science and innovation parks. The 'Triple Helix' knowledge model, referenced above, emphasizes three 'helices', three domains that are all relevant for an innovation system: academia/universities, industry and state/government. As the research is closely related to the "Triple Helix" knowledge triangle model, therefore the different ecosystem types can be also assessed in the light of the founder forms derived from the triple helix model and their combinations. Although this can be subject of further researches, the current survey sample is also well-representing the various types of innovation ecosystems in view of triple helix approach (Table 2).

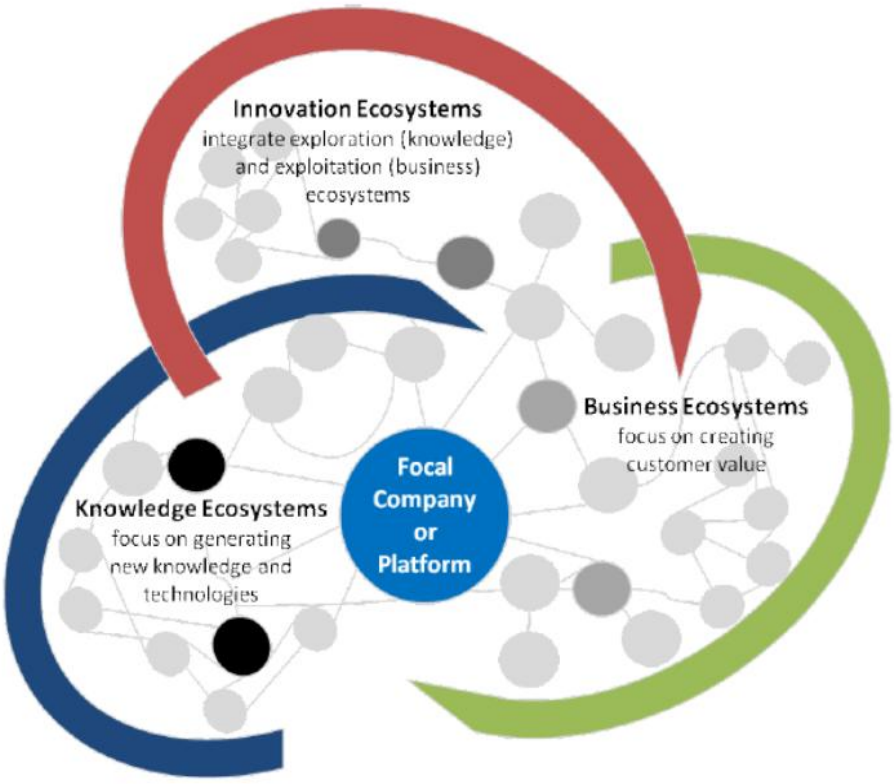

Fig. 1. Ecosystem types (Source: Katri, 2015)

Table 2. Sample group of the presented survey in view of triple helix approaches

Triple helix groups, as founders		No. of surveyed park
Single-party (gov't)	Government	2
	Government	7
	City	4
Single-party (academia)	University	5
	University	11
	University	12
Single-party (private)	Private	3
Double-party	Government, Industry	9
	City, University	10
Triple-party	Government, University, City, Private	1
	Region, University, Industry	6
	Government, University, Private	8

4. RESULTS

Based on the responses from the approached European science parks, the results of the survey are presented below. The correlations between them will be analyzed in more detail in the following section when evaluating the research results.

Sectoral focus: Sectoral feature is relevant both from industry and research organizations point of view, being present in the park.

Analysis of the sectoral focus is important because it plays a major role in the identification of the types of innovation ecosystem and the characteristics of the complex system discussed so far. The more a park oscillates between "chaos and equilibrium", the more it can be characterized by complex system characteristics. One of the feature related to this, is the diversity of the sectors being present in the park.

The current paper build on earlier researches of the authors which established the four-type classification of the innovation ecosystems according to the scheme shown in Fig. 2, considering both the number of sectors and presence of dominant sectors or players there. The presented research is an example, how this scheme can be used to classify park types during their analysis, it was not the purpose to define or evaluate selected or found sectors.

In order to evaluate this aspects, the following questions, as alternative answers, have been taken:

a) Sectoral diversity (horizontal aspect):
- The park is very focused, with a few types of sectors.
- The park is not focused, with many types of sectors.

b) Sectoral intensity (vertical aspect):
- The park is built around a large company.
- There is no one dominant sector in the park.

Fig. 2 shows the number of answers in the related category, in this research, it was not the intention to make a quantitative survey. However, in further research planned, the horizontal axis can be quantified by asking the number of the specific sectors, whilst the vertical axis can represent the exact number of the organizations counted.

Of the 12 European parks, the majority (5 parks) declared that there is a dominant sector in the park. If there is a dominant sector with a slight sectoral dispersion, which means that one or more organizations belonging to focused scope of industry are operating there, attracting other actors to the park, or that a supply chain has been established around them locally.

The next case is where a dominant sector is present in the park, but a wide range of sectors can be observed alongside it. This reflects the dominance of several larger industries there and the attraction of several smaller supply chains. In this case, there is an even distribution of players between the different sectors.

In the lower left section, the absence of a dominant sector is assumed and the sectors are not diverse. This implies that it could be a small park with a small number of actors in a small number of sectors, which is not the case for most high-performing science parks.

The fourth option is, when the absence of a dominant sector in the presence of a wide range

of sectors, is typical. This is one of the noticeable category found in the park types, these science parks are rather the general science parks, where either as a consequence of chance or consciously no sectoral centrality has developed/was not allowed to develop. So the park management has allowed the park to grow without defining an operational area or purpose for it.

These explained options are illustrated in Fig. 2, with demonstration of usage of the four-type scheme method at the analyzed 12 parks.

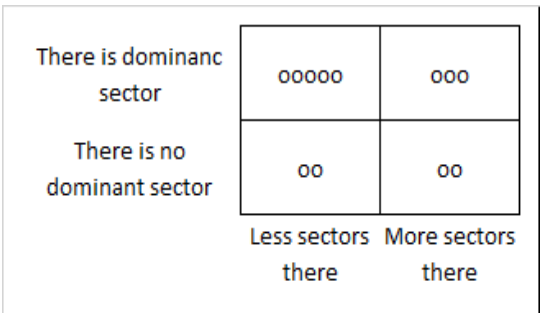

Fig. 2. Types of sectoral focus

Park community diversity: The park community reflects the presence of relevant actors in view of the triple helix model.

Fig. 3 is related to the diversity of the resident members of a park, whereby different types of park types include several types of actors.

Small and medium-sized enterprises, university presence, start-up initiatives, research laboratories and service companies are all present in the responding parks, while large organizations are less present, based on the previous question, and industrial enterprises (industrial type parks) and educational operators are not typically present. By educational actors we mean actors other than universities.

The actors present at the parks can be cross-checked with the relevant groups of establishments as shown by Table 3. There are some typical patterns (e.g. university or research group is available at each park, SME's are present in nearly at all parks, etc.), but further, large scale research is needed to evaluate these correlations in depth. Nevertheless, such aspect is advised to focus at additional research.

Human versus technology orientation: Fig. 4 shows the pattern of technological and human orientations, with the highest number of respondents indicating technological and human orientations altogether.

The larger circle refers to the larger number of respective respondents. The two axes show the representation of the two aspects, evaluated by the respondents in a scale 1 to 6.

As it can be observed, the respondent gave very high answers on question of "how important is the presence of human capabilities" (4 cases with score 5 and 8 cases with score 6).

Similarly, the respondent gave rather high answers on question of "how important is the presence of technological capabilities" (3 cases with score 4; 4 cases with score 5 and 5 cases with score 6).

The observed pattern means that usually parks consider both the continuous development of technology and the continuous training of human resources to be important.

The reason for this might be that in the surveyed high-performing science and technology parks, the balance of human and technological capabilities is found as key for success.

Interaction among actors: The interaction between actors is the real dynamic generated by the logic of triple helix model.

Fig. 5 shows that in 25% of the parks it is typical that the established actors act as buyers/suppliers for each other, so some interaction can be observed, possibly even joint projects. This is important, because in the concept of an innovation ecosystem, it can be observed that the system should encourage cooperation between actors, rather than seeing the entrants as competitors. The classic supplier-customer relationships can be the basis for deeper collaborations, like longer-term partnerships or strategic co-operations, beyond the usual and classic business relations.

Science and technology parks, as specific innovation ecosystems, are usually mix of research sphere and commercial economy, The joint presence of these two fields are well-presented by the results of the survey at the analysed parks. The nature of the collaboration

among the research and market players might occur in several ways:

- Partnerships (e.g. joint research projects, research consortia, research alliances, etc.),
- Knowledge transfer activities (e.g. scientific knowledge from universities toward industry, transfer of leading technological knowledge from industry to universities, joint education projects, etc.).

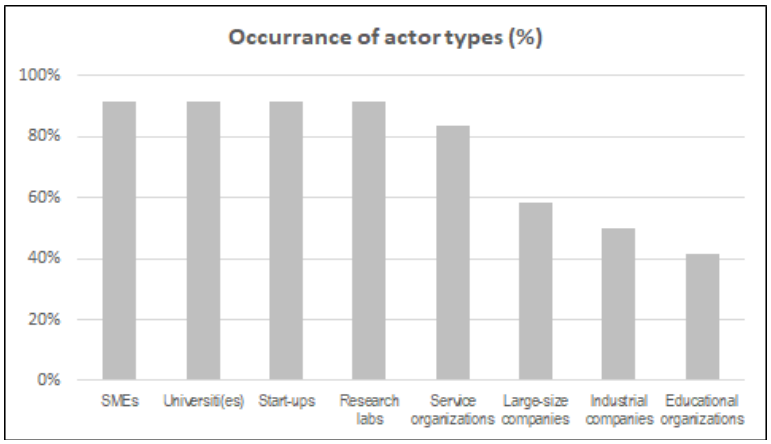

Fig. 3. Heterogenity of park management elements

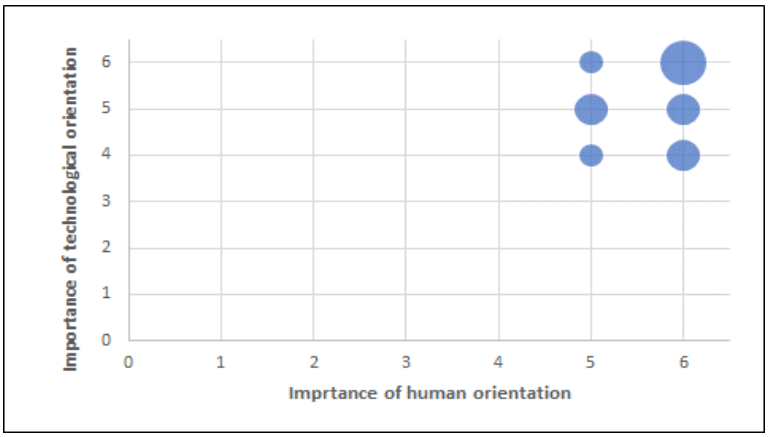

Fig. 4. View of technology and human orientation

Table 3. Actors and park establishment groups

No. of park	Industrial companies	Service enterprises	SME's	Large organiza-tions	University	Students or education players	Start-up business initiatives	Research laboratories	Established by (based on Triple Helix model groups)
1	1	1	1	1	1	1	1	1	Government, University, City, Private
2		1	1		1		1	1	Government
3	1	1	1	1	1	1	1	1	Private
4	1	1	1		1		1	1	City
5		1					1	1	University
6		1	1		1		1		Region, University, Industry
7	1	1	1	1	1	1	1	1	Government
8			1		1			1	Government, University, Private
9	1	1	1	1	1	1	1	1	Government, Industry
10			1	1	1		1	1	City, University
11	1	1	1	1	1	1	1	1	University
12		1	1	1	1		1	1	University

However, the firmly different culture and organizational features of scientific and commercial players can generate certain challenges for these collaborations. Typically, academic players focus on the earlier research phases while the market players act on at the other end of the research and development focus. As a consequence of this, the objectives, scope fo activity and organizational behavior are completely and naturally different. That requires thorough way of management when both parties are present in a collaboration. The role of intermediary players (e.g. incubators, start-ups, etc.) is also important, as they can interact in the phases after establishment of new scientific results, but still before market launch.

These aspects are indirectly reflected in the results shown by Fig. 3, as they were not the basic objectives of the current research. Nevertheless, it might be concluded that such characteristics should be survey in detail when organizing a large-scale research in the subject.

Presence of business model-like elements: The business model-like approach is related to the ecosystem-level perspective, which also reflects the nature of a park, whether it is more industrial, governmental or academic type, or a kind of mix of these.

Fig. 6 analyses whether the elements of the business model, which have been previously reported in severals of the authors' publications, are present in the different types of parks. It can be seen that the development of skills and competences is 100% present in all responding parks, which is closely related to the question asked in the previous section about the importance of technology and the importance of continuous training/development of human resources.

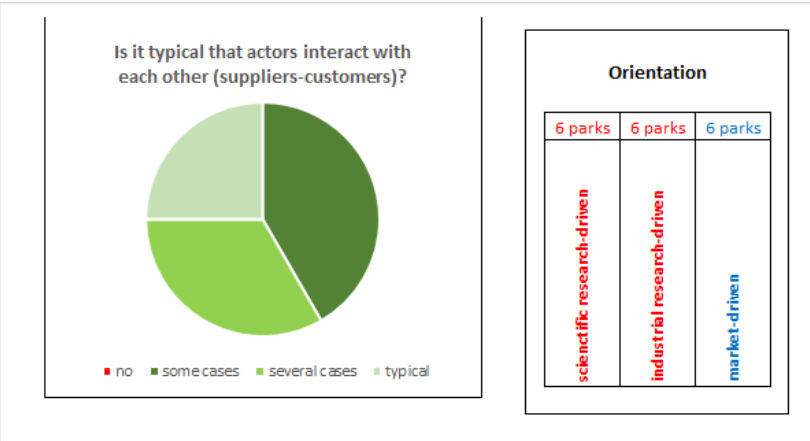

Fig. 5. Relations among actors in the park

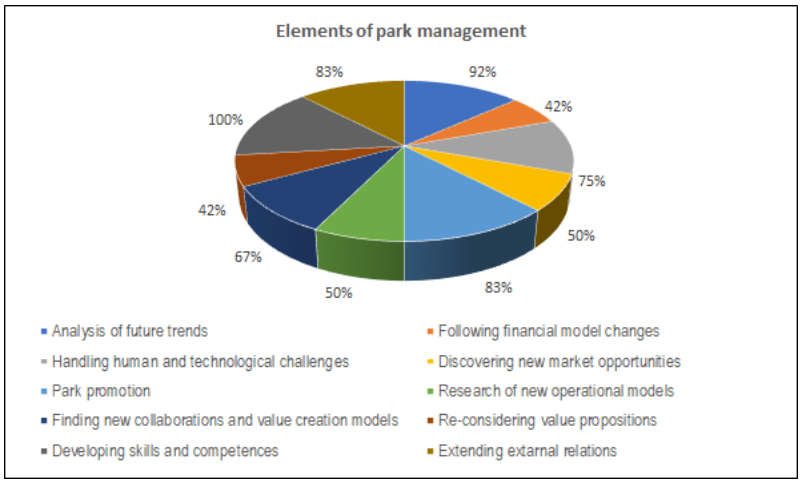

Fig. 6. Business model-like elements of park management

Additionally, 92% of park managers consider the analysis of future trends related to Industry 4.0 to be very important. Next, 83% consider the promotion of the park and the monitoring and analysis of external relations to be the most important.

The answers to this question are important for the research because they confirm the correlation between the elements of the operating model previously researched and the main trends observed in the operation of parks aggregated into an innovation ecosystem-level business approach.

These aspects can be further researched with park-level organizations which are responsible for offering the management framework for the complete innovation ecosystem. The key performance outcomes usually depend upon the founders or owners of the park, considering its mission and vision. However, most probably, the basic sustainability objectives should be present. They might include not only the financial measurements, but also monitoring of the generated impacts, ESG (Environmental, Social, Governance) concepts, corporate social responsibility and environmental aspects, too.

5. DISCUSSION

While the research results have been presented above, this section explains in detail the results-based evaluation. The basic research question that is to be addressed in this paper is what type of innovation ecosystem can be distinguished based on the research results and the previous literature review. The second research question is to what extent can the parks assessed be characterized by the features of complexity theory.

The questions in the questionnaire approach this issue from six directions. These are the followings:

(a) Is there a dominant sector or industry in the park and is there a diversity of sectors?
(b) Which industry players are present in the park?
(c) To what extent do you consider the continuous development and innovation of technology and human resources in the park to be important?
(d) Are there any interactions, links or relations between the operators established in the park?
(e) What type of activities is the park management organization involved in?

After detailed analysis of the answers to the questionnaire, the following conclusions can be drawn by analyzing each of the components.

Based on the results of the dominant sectoral presence (a) or sectoral diversity question on the types of parks, four types of parks can be distinguished as shown in Fig. 2. Since we can classify specific parks in each of the four cases and there were no outliers in this set of questions, we can conclude that the four types cover the "market" in terms of types of parks. So, there is a dominant sectoral park, and there is a park where there is no dominant sectoral dominance, and there is also a diversity of sectors in certain types of parks, and there is also an ecosystem of respondents where there has been relatively little shift towards sectoral diversity. This is very much the basis for the answer to the first research question.

As a second aspect, the authors examined the established actors according to their industry breakdown (b). This point may be a limitation of the research, as other types of industry classification may occur in addition to the eight categories asked in the questionnaire, but these eight types were identified based on the authors' prior research and practical experience. This part of the research can be considered as an area to be further extended in the future.

However, as the results confirm a high proportion of the possible answers to the assumption that a number of actors from several industries can be found in a given innovation ecosystem, we can assume that some of the features of complexity theory related to the second research question are confirmed, as the diversity of actors can form the basis for a complex operation. The results related to the second point also form the basis for the answer to the first research question.

In the followings, the authors addressed the issue of technological development and the continuous improvement of human resources. The results show that it is important for all actors to adapt quickly and reduce the reaction time to the technological development and information pressure that is most prevalent today. This fact further strengthens the issue that underpins the complexity theory, as technological development and the continuous improvement of human resources enable the individual resident

organizations in the parks to carry out increasingly complex and innovative processes, and therefore the complexity theory can be increasingly identified with as it approaches the “borderline of chaos and equilibrium”.

However, the importance and better grounding of this issue is illustrated in Fig. 5, which answers the question of interactions, relationships and relations between the actors involved. It can be seen that in 60% of the cases there is a relationship between the different actors, even if they are each other's customers or suppliers. This area will be another very important basis for further research and complexity theory-based operations.

The last question puts the organization of park management at the heart of the investigation. The ten themes raised featured heavily in the responses and processes of all respondents. This means that, on the one hand, the topic of the operational areas raised is unquestionable and, on the other hand, the extent to which management influences park operations can be largely confirmed when identifying types of park.

6. CONCLUSION

The final objective is an innovation ecosystem is to generate value for the interested parties, which can be the clients, industrial player, investors, researchers, governmental organizations or other financing agents. Thus, the main interest and result of such knowledge ecosystems is to generate new knowledge through joint research work, collaboration or development of a solid and robust knowledge base. That is why the current research dealt with potential park characteristics through which these mechanisms can be better understood.

In this research, the authors focused on surveying of characteristics of well-functioning European innovation ecosystems and evaluation of interrelationships of the characteristics. The research questions posed propose the identification of types of innovation ecosystems and the complexity theory-based innovation ecosystem functioning.

In the course of the research, the authors examined the sectoral focus of innovation ecosystems, the breadth of park functions, the position of human vs. technological focus, the presence of cooperation (commercial vs. research economy), the prosperity and success of the park, and the characteristics of park management in the European science parks surveyed. The concept and functioning of innovation ecosystems can be related to research on the characteristics of complex systems, based on previous research, and the research (questionnaire survey) therefore covers several topics of different nature.

Taking into account the theoretical considerations detailed above, and building on the authors' previous research, the authors distinguish five different types of innovation ecosystems in the present study. These types are also in line with the main elements of the innovation ecosystem model presented in previous publications of the authors, which represent the possible functional areas of science and innovation parks.

The key outcomes of the analyzed aspects are feasible for differentiating various science and technology parks:

1. Sectoral focus,
2. Actor diversity,
3. Human/technology focus
4. Collaborations,
5. Nature of park – presence of R&D
6. Park-level management model elements

This can serve a 6-factor descriptive model for classification of the various innovation ecosystems, to help further research in order to understand cause and effect relations of the system factors.
At future research, when having large database, statistical correlations might be analyzed by using more quantitative methods.

7. LIMITATIONS

As the questionnaire is not exhaustive (it does not include responses from all IASP members and does not capture all the innovation ecosystems found), it has limitations.

- The survey sample of 12 parks is not representing the large-size sample of science and technology parks. The purpose of the current research was not to process representative sample results, but use the survey sample to validate how the identified characteristics can be (or if they can be) analysed.
- Some features of the six analysed areas show limited depth, the discussions, and

conclusions pointed out the need of more detailed analysis aspects in these fields: collaborations, challenges of cooperations between research organizations and market players.

- Although the current research focused purely on processing of the identified innovation ecosystem characteristics, when organizing similar research in the future, impacts of innovations ecosystems might be also considered to evaluate complex sustainability aspects, as key rationale for establishment and management of such parks.

Nevertheless, as the current research was intended to act as a preliminary small-scale survey with validation purpose, it had no impact on the final conclusions. Nevertheless, the outcomes of the research serve as basis for the next-level, high-scale research in a similar topic. Also, further research can include impact of assessing the characteristics of innovation ecosystems on business and society.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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