Journal of Engineering and Technology Management 51 (2019) 21–32

Contents lists available at ScienceDirect

Journal of Engineering and Technology Management

journal homepage: www.elsevier.com/locate/jengtecman

Multi level network management – A method for managing inter-organizational innovation networks

Jan-Patrick Cap[a,*], Erik Blaich[a], Holger Kohl[b], Ariane von Raesfeld[c], Rainer Harms[c], Markus Will[a]

[a] Fraunhofer Institute for Production Systems and Design Technology, Pascalstr. 8-9, 10587, Berlin, Germany
[b] Technical University of Berlin, Institute for Machine Tools and Factory Management (IWF), Pascalstr. 8-9, 10587, Berlin, Germany
[c] University of Twente, Drienerlolaan 5, 7522, Enschede, the Netherlands

ARTICLE INFO

JEL classifications:
O
Y
Z

Keywords:
Innovation networks
Network management
RTO management
Innovation management
Network assessment
Ego network perspective
Whole network perspective

ABSTRACT

Collaboration in inter-organizational networks is a major driver of innovation. Nevertheless, methods that practitioners can rely upon for managing innovation networks are still scarce. This research fills this gap by providing an approach that increases innovation output by intensifying collaboration in networks. An action research methodology with two cycles of action was adopted. The first cycle develops a method of network assessment designed to evaluate a network's collaboration potential. The second cycle iteratively builds on the first cycle and extends the method by a managerial approach to network management on an individual level.

1. Introduction

Networks have become a central governance mode that organizations use to manage innovation (Ahuja, 2000; Schilling and Phelps, 2007; Raesfeld et al., 2012; Corral de Zubielqui et al., 2016). To achieve the benefits and to overcome barriers to networked innovation, active network management is advocated (Dhanaraj and Parkhe, 2006; Möller and Rajala, 2007). To actively manage networks, managers may need a network management method that is actionable. However, the literature reveals very few network management methods that practitioners can rely on (Sydow, 2010; Becker et al., 2011; Bogenstahl, 2012).

Methods for managing innovation networks exist but have two principal limitations (Möller and Halinen, 1999; Dhanaraj and Parkhe, 2006; Tikkanen and Renko, 2006; Ford et al., 2011): (1) In the specific case of innovation networks, only frameworks are available. These conceptual models of innovation networks provide no actionable methods that practitioners can apply directly. (2) Practical methods that do exist for network management in general (but not specifically for innovation networks) take the view of the individual actor, optimizing individual outcomes but not the outcomes of the overall network (Goerzen, 2005; Ruokonen et al., 2006). This brings us to the conclusion that no method exists that enables the strategic management of a whole innovation network.

Given the lack of network management methods that are actionable and specific to innovation networks, the goals of this research were twofold. The first goal was to develop a method geared to increasing innovation output from innovation networks by improving

* Corresponding author.
E-mail address: jan-patrick.cap@ipk.fraunhofer.de (J.-P. Cap).

https://doi.org/10.1016/j.jengtecman.2019.02.001
Received 9 August 2017; Received in revised form 11 December 2018; Accepted 8 February 2019

collaboration between their actors. The second goal was to evaluate the feasibility of the method thus developed. Consequently, this paper presents a network management method specifically developed for innovation networks. The method measures current and potential future network connections. It operates on both the whole network level and the individual level. It provides strategic implications on network management for each network actor.

We provide the conceptual background on innovation networks and conclude Chapter 2 with an account of the key gaps in current research. We go on to describe the research context, purpose and method, concluding Chapter 3 with the lessons learned from the first cycle of our research. In Chapter 4, we describe the second cycle of action research, where we develop the multi-level innovation network management method. This paper then concludes with a general discussion of our innovation network management method.

2. Background

2.1. Innovation Networks: key elements and management

Innovation networks are a form of economic coordination of innovation activities, in which legally autonomous but, in the context of innovation, economically dependent actors establish stable, complex and reciprocal social relationships (Duschek, 2002). We define innovation networks as inter-organizational networks constituted by a defined set of actors who collaborate for the sake of innovation and are governed by the interests of the network.

Two main criteria need to be defined when analyzing an innovation network: (1) to define innovation networks, the distinction between who belongs and who does not belong to a network has to be made (Snehota and Hakansson, 1995). This distinction is needed to facilitate the management of inter-organizational networks (Ojasalo, 2008); (2) to define network connections, the exchanged content of the network needs to be identified (Jansen, 2006). Possible criteria of investigation are joint action (Raesfeld et al., 2012) or collaborative linkages between leading firms such as joint ventures, joint research and technology-sharing agreements (Ahuja, 2000). These approaches have two disadvantages for practitioners. First, they describe networks of the past and are backward looking. Second, they are limited to describing officially documented connections. Practitioners need an assessment of a network's connections that are current, whether formally documented or not.

Network management is a managerial approach that is concerned with designing and managing networks (Huuskonen and Kourula, 2012). It comprises the design, steering and development of all cross-organizational relationships at normative, strategic and operational levels in a network of legally independent but somewhat economically dependent companies (Petry, 2006). Its four key functions are (1) the selection of suitable actors, (2) the regulation of activities and relationships, (3) the allocation of resources, and (4) the economic evaluation of inter-organizational relationships (Sydow and Duschek, 2013).

The goals of network management are to increase performance and network evolution (Huuskonen and Kourula, 2012). Network performance is reflected in network effectiveness, network efficiency, organizational performance, and management efficacy (Huuskonen and Kourula, 2012). Organizational performance refers to how an organization performs, for example in its degree of innovativeness (Capaldo, 2007). Network evolution refers to the development of network structures and network.

Three modes of network management governance are identified (Popp et al., 2013): (1) shared governance by all network members; (2) a lead agency, where a network member governs the network, e.g. referred to in Dhanaraj and Parkhe (2006) as a 'hub firm' that is identified by status and power; or (3) a Network Administrative Organization (NAO), which is a separate unit that administers the network.

2.2. Different collaboration foci within innovation networks

Although R&D collaboration is a central aspect of innovation networks (Ojasalo, 2008), there are other activities that contribute to innovation such as scientific, technological, organizational, financial and commercial steps (OECD, 2005). While only R&D and the acquisition of machinery incorporating new technology are clearly technological, product or process-innovation activities, other activities may be required to implement those innovations (OECD, 2005). Accordingly, they build possible topics or foci of collaboration in innovation networks. For example, types of innovation network have been described according to the emphasis they place on functions such as R&D, production and sales (Petry, 2006), procurement, R&D, service provision, and marketing (Friese, 1998), or innovation, procurement, production, distribution, and service (Haritz, 2000).

2.3. Perspectives on inter-organizational networks

Networks can be analyzed on different levels (Provan et al., 2007; Zaheer et al., 2010; Popp et al., 2013): (1) The single actor, i.e. an ego. On the ego level, analyses focus on the effects that the connections between the ego and its alters have on the ego. (2) Groups, communities or clusters in the network. On the group level, research focuses on groups, communities and clusters. These are sub-networks of the whole network. (3) The entire network. On the whole network level, the focus lies on the characteristics, behavior and outcomes of the network as a whole.

Network management draws on all network perspectives. An organization that manages its own network, focusing on the effects on itself that result from the connections to its alters, views network management on the ego level. An organization that focuses on orchestrating an entire network, bearing in mind the interest of all actors with the goal of increasing the overall outcome of the network, envisions network management on the whole network level. The analysis of groups is part of the whole network perspective.

2.4. Collaboration intensity and tie composition: Key network metrics

Taking a structural perspective, networks have been defined as "a set of nodes connected by a set of ties" (Borgatti and Foster, 2003, p. 992). Ties are the connections, and nodes are the actors. Two of the most prominent concepts used to describe network structure are density and tie strength.

'Strength' describes the quality of the relationship between two actors (Granovetter, 1973). Strong ties are long-lasting relationships, intense and frequent collaboration and repeated partnering over time (Phelps et al., 2012). Weak ties are loose relationships with infrequent contact, often amongst a heterogeneous set of actors (Elfring and Hulsink, 2003). Both offer different advantages. Strong ties are more suitable for the transfer of tacit knowledge (Uzzi and Lancaster, 2003), fine-grained information (Uzzi, 1996), and for organizational-knowledge creation (Capaldo, 2007; Lavie et al., 2007; Sampson, 2007). The creation and transmission of tacit knowledge require face-to-face interaction (Capdevila, 2017). Weak ties are more effective in the transfer of explicit knowledge, and in information search (Uzzi and Lancaster, 2003), especially regarding access to new information (Witt, 2004). Granovetter (1973) made a case for the strength of weak ties by showing that information that is spread through weak ties has a better chance of reaching a greater number of people (March, 1991; Nooteboom et al., 2007). In this context, exploration is related to weak ties and exploitation to strong ties (Jansen, 2006; Nooteboom et al., 2007; Partanen et al., 2014).

Density is a measure of the overall level of connectedness amongst the actors of a network (Provan et al., 2007). Density is the percentage of all established ties as a share of all possible ties in a network (Ahuja, 2000; Provan et al., 2007; Schilling and Phelps, 2007). It has been argued that, for effective exploration, a dense network is beneficial. For effective exploitation, a low density is required (Nooteboom and Gilsing, 2005).

2.5. Literature gap

Effective and efficient network management requires actionable methods. Yet, the development of these methods is in its infancy. The task of managing networks is often exacerbated by poor knowledge about the practical management of networks (Becker et al., 2011). Bogenstahl (2012) stresses the demand for management to steer and control network activities. Steering and controlling have been insufficiently covered in network research. Sydow (2010) points out that, despite the considerable variety of research on networks, much is still unknown about practical network management. Becker et al. (2011) agree that literature dealing with the phenomenon of networks under practical considerations is still scarce, underscoring the notion that the transfer of traditional management practices to the network context is at present inadequate.

Existing network management methods often fail to meet the demand of practitioners, as the following examples illustrate. First, Ruokonen et al. (2006) suggest a network management framework that assigns four different partnership strategies based on the specific requirement of partners; this can be low or high in terms of product-specific and market-specific knowledge, and it can be technologically simple or complex in respect of the firm's products. The four partnership strategies resulting are partner selection, partner motivation, network management, and flexible network development. This method is only applicable to the ego network level and is designed specifically for the internationalization of small software firms. While the method is actionable, it provides only very generic strategies and offers no guidance on the management of network relationships.

Second, Keast and Hampson (2007) developed a framework for the process of relationship management. They emphasize four key network management tasks: activating (identifying and selecting the right actors), framing (establishing and influencing operating rules, values and norms of a network), mobilizing (formulating a common vision and mission) and synthesizing (dealing with conflicts and aligning the actors to common goals). While this approach may be applicable to both the ego perspective and the whole network perspective, it fails to provide concrete guidance on operationalization of the four steps, such as the selection of network actors.

Third, Jüttner and Schlange (1996) provide a relationship-oriented method of network management that answers five questions: What are the strategic situations to be analyzed? On which should actors focus? Who determines the nature of the relationships? What role in the network does each actor perform? What leverage and what steering potential do each actor possess? This approach provides very detailed descriptions on how to implement operationalization. The method solely fits the ego-level perspective.

Network research needs to be tailored more to the demands of practitioners. In particular, the network as a whole has seldom been the subject of practitioner advice (Provan et al., 2007). The greater part of network research has focused on the ego level (Zaheer et al., 2010). Indeed, many network management methods have been designed to fit the ego perspective (Jüttner and Schlange, 1996). Acknowledging the growing demand for advice focused on the whole network perspective, some authors have approached innovation network management from this viewpoint too (Tikkanen and Renko, 2006). However, research – as much as existing network management methods – usually focuses on one of these standpoints, and principally on the ego perspective. Research that seeks to link the ego level and the whole network level seems to be non-existent. Nevertheless, practitioners need to consider both perspectives. Network managers need strategic guidance on how to influence whole networks, and individual network actors need strategic guidance on how to manage their individual relationships. The best results can be expected when both are aligned and follow the same overall strategy.

3. The network assessment (cycle 1)

3.1. Context and purpose

This research was conducted in the context of a Research and Technology Organization (RTO). RTOs link research and private sector innovation with the task of transferring scientific results to the private sector (OECD, 2011). Examples of RTOs are the Fraunhofer Society in Germany, TNO in the Netherlands, VTT in Finland, Tecnalia in Spain and SINTEC in Norway (OECD, 2011). This paper's network is mandated. Mandated networks are influenced by parties other than the actors themselves and usually have greater incentive to work together (Baum et al., 2003; Zaheer and Soda, 2009; Ahuja et al., 2012; Popp et al., 2013). In contrast, emergent networks are built without external influence, and members have a higher intrinsic motivation to work together. The network is orchestrated by a network administrative organization (NAO).

The network was established in 2012 and consists of 25 institutes. The institutes are partly independent organizations who operate under the same branding. These institutes constitute the research body of the RTO. The NAO orchestrates the network linking the institutes. The task of the NAO is to strategically investigate the specializations in the network and arising trends, and to make suggestions on how to develop the network. These suggestions are discussed with the actors. Possible extensions of the network include new tasks for actors or adding new actors to the network. A strategic goal of the NAO is to improve collaboration amongst the actors, and to leverage synergy effects that can help increase the innovation output of the network as a whole. For this purpose, the NAO needs a network management method that will promote a more intense collaboration amongst the network actors.

3.2. The network assessment method: the starting point

The trigger for developing the Network Assessment Method (NAM) originated from the demand of the NAO for an actionable method to manage a networked RTO. No applicable approach could be found in the literature. To develop the NAM, the requirements were discussed with the NAO.

The first requirement is a participative approach in which the actors are integrated into the network management process. The goal of the participatory approach is to increase motivation and tap into the knowledge of all partners. The second requirement is the quantitative measurement of collaboration based on key network figures and their visualization. Visualization in the form of network graphs is used as an aid to discussion, supported by clusters identified from within the overall network where network actors could collaborate on a specific topic. Network figures allow the NAM to numerically track the progress of the network. The difference between the current status and the future status was determined and labelled 'the collaboration gap'. Visualization in form of network graphs will be used as a visual aid for the discussions supported by identified clusters within the overall network in which network actors could collaborate around a specific topic. A final requirement is to derive and prioritize actions geared to an increase in the network's collaboration and innovation capability. The result of this process is a vision of a potential future network structure and an idea of how much the current status differs from it. In other words, it provides an assessment of the unleveraged collaboration potential of the network.

3.3. Choice of action research

A key goal of this research is to develop a practical application. Tripp (2005) gives an overview of different research approaches. Action research lies between scientific enquiry and routine practice from daily application (see Table 1).

Due to its characteristics, action research was chosen as the most suitable way to achieve a compromise between a structured research process and applicable results. Action research is conducted in a participative manner concurrent with action. It can be described as a sequence of events that build on each other in an approach to problem solving. Because of these characteristics, action research can construct a suitable framework for the application of the developed method and its iterative improvement under genuine conditions (Coughlan and Coghlan, 2002; Mertler, 2017; Rowell et al., 2017). Rowell et al. (2017) provide a framework for action research. Mertler (2017) and Coughlan and Coghlan (2002) provide a similar practical and cycle-based methodology to follow when

Table 1
Eleven characteristic of action research (extended by authors based on Tripp, 2005).

Characteristic	Routine practice	Action research	Scientific research
Solution approach	Habitual	Innovative	Original resourced
Regularity	Continuous	Continual	Occasional
Methodology	Responsive contingency driven	Pro-active strategically driven	Methodologically driven
Participation	Individual	Participatory	Collaborative, collegial
Research approach	Naturalistic	Interventionist	Experimental
Task source	Unexamined	Problematized	Commissioned
Source of explanation	Experienced	Deliberated	Argued
Documentation	Unarticulated	Documented	Peer reviewed
Level of solution	Pragmatic	Understood	Explained, theorised
Validity	Context specific		Generalised
Publication	Private	Disseminated	Published

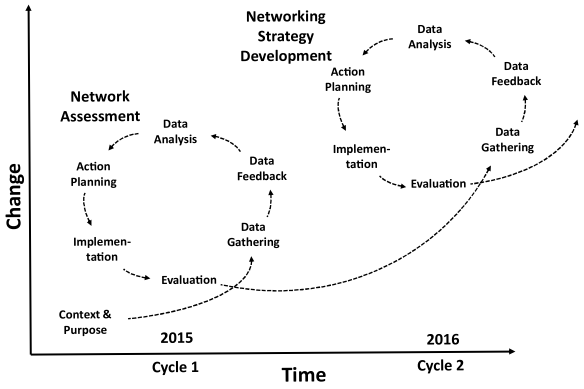


Fig. 1. The two cycles of action research, depiction based on Battistella et al. (2015), p.6.

conducting an action research project. Coughlan and Coghlan (2002) analyze the action research literature and propose a model of action research for managers and researchers. Due to its ample grounding in the literature, its wide-spread utilization, and its practical benefits, this paper's research methodology follows the action research approach described by Coughlan and Coghlan (2002). We argue that the specific choice of action research framework may influence the outcome of this research only in a minor way, as long as the frameworks share the basic requirements of action research (see Table 1).

The action research approach has three steps (Coughlan and Coghlan, 2002). First, the context and purpose of the research are defined. The second step is the execution (data gathering, data feedback, data analysis, action planning, implementation and evaluation). Finally, the research is monitored. Action research is iterative so that continuous learning is achieved (Coughlan and Coghlan, 2002). In this research project, two cycles of action research were conducted. In the first cycle, we developed a network assessment method. In the second cycle, we added a method for developing individual networking strategies (see Fig. 1).

3.4. Execution of the six main steps of action research

3.4.1. Data gathering

To gather data about the current status and future potential of collaborations, the key informant approach was employed (John and Reve, 1982). We used surveys that were sent to directors of the institutes, since they were directly responsible for strategic networking decisions. During the first cycle, 18 actors returned the questionnaire. During the second cycle, we received 24 responses. As the whole network consists of 25 institutes, we achieved a high response rate.

The current collaboration status describes the current intensity of collaboration between two actors. The future collaboration potential measures collaboration opportunities that actors forecast will emerge in the coming five years. Since all actors rate each actor and are rated by every other actor, there are two ratings for the same connection. Current collaboration status and future collaboration potential were measured by self-assessment questionnaires from the key informants on a scale of 0–10. The scale follows following logics for status: (0) collaboration creates no benefits, no collaboration takes place currently; (5) collaboration creates some benefits, collaboration on some level takes place currently; (10) collaboration creates great benefits, collaboration on many different levels takes currently place. The scale follows following logics for potential: (0) collaboration could not create benefits. No collaboration will take place in the future; (5) collaboration could create some benefits, collaboration on some level can take place in the future; (10) collaboration could create great benefits, collaboration on many different levels can take place in the future.

After consultation with the NAO, three topics were given special priority and, therefore, defined as collaboration foci of the network (see Section 2.2). These were resource collaboration, research collaboration, and customer collaboration. The foci match those of Friese (1998) who emphasized collaboration in production (resource focus), R&D collaboration (research focus), and marketing collaboration (customer focus). They also correspond to the three-stage innovation model of RTOs (EARTO, 2016), which includes the three stages of competence building (resource focus), technology development (research focus), and diffusion (customer focus). Table 2 provides details on the three collaboration foci identified. We assessed the current and future collaboration potential for each of the three collaboration foci.

3.4.2. Data feedback

First, based on raw data, network graphs were visualized using Gephi (Bastian et al., 2009; Jacomy et al., 2014). Within Gephi, clusters were defined using the Louvain Algorithm (Aynaud and Guillaume, 2011). This simple algorithm maximizes the modularity of a network and, thereby, provides a quick and unsupervised result of the potential clusters within a network.

Furthermore, network-structure measures provide numerical values for the network structure. Network density and the ratio of strong and weak ties were chosen as they allow us to draw conclusions on network effectiveness in terms of exploration and exploitation. The goal of an RTO (see 3.1) is to conduct research and bring innovation to the market. Therefore, in the context of RTOs, exploration and exploitation are important. Hence, an effective network should contain strong ties as well as weak ties. The density

Table 2
Definitions, levels and benefits of the three collaboration foci.

	Resource Collaboration	Research Collaboration	Customer Collaboration
Definition	Resource collaboration is defined by two or more actors who share the same resource (e.g. machinery, human resources, analytics) without any or very little additional effort.	Research collaboration is defined by two or more actors who combine their knowledge and technologies to work together on a research topic a single player could not master on its own.	A customer collaboration is defined by two or more actors who target the same customers through joint activities and/or jointly deliver projects to the same customer.
Levels	Collaboration in terms of purchasing or using equipment and software as well as sharing external services (e.g. training, consulting) and human resources and transferring existing knowledge.	Building up competence fields for future technologies and current transversal research topics (Technology Push).	Collaboration in terms of market analysis, marketing and sales activities, based on current demand of the industry (Market Pull).
Benefit	Increase efficiency, optimize costs and access broader resource base.	Drive national innovation activities and develop new technologies for national industry.	Increase revenues, master broader project scopes and deliver complex solutions.

should be in a range that allows exploration and exploitation. In this sense, the overall goal is not to increase strong ties or density to the maximum but to keep it in a range that is effective for each respective application case.

3.4.3. Data analysis

Data was analyzed collaboratively between action researchers, the NAO and the actors (Coughlan and Coghlan, 2002) in collaboration workshops. In these workshops, the data was presented (raw data from questionnaires, network graphs and network structure measures). It was analyzed and discussed jointly to identify potential for improvement concerning collaboration within the network. In the first cycle, the analysis resulted in the identification of clusters within the whole network.

3.4.4. Action planning

Following data analysis, steps to intensify collaboration were planned in line with the action research approach (Coughlan and Coghlan, 2002). The need to conduct this step jointly with all involved parties was again emphasized. Plans for closer cooperation in the key clusters (resulting from step one) were agreed by the actors.

3.4.5. Implementation

The action plans were implemented over the course of the following months, for example, by initiating new joint projects, organizing joint events, and intensifying research collaboration. Implementation of the networking strategies during the second research cycle was started in the same setting. Based on the results from this collaboration workshop, individual actors started to consider more explicit collaboration opportunities with others. Again, measures were taken to intensify collaboration within the scope of the three collaboration foci (customer, resource and research).

3.4.6. Evaluation

The evaluation step is about reflecting on the actions taken. It provides a basis for a more successful iteration in the next cycle of action research (Coughlan and Coghlan, 2002). As a standard mode of evaluation, four questions were asked at the end of each cycle (Coughlan and Coghlan, 2002; Battistella et al., 2015): Was the original diagnosis correct? Was the correct action taken? Did the action taken overcome the initial problems? What can be fed into the next cycle?

Serving not only as an induction meeting for this action research project but also as an evaluation meeting, the collaboration workshop that was initially conducted to analyze the network data gathered was repeated the following year. This enables an iterative process of yearly action research cycles. The NAM monitors the network development over time. Therefore, the progress of the innovation network in terms of collaboration intensity can be checked repeatedly. The collaboration workshop served as an evaluation meeting for both action research cycles.

3.5. Monitoring

Monitoring is a meta-step that occurs through all cycles of action research (Coughlan and Coghlan (2002). Monitoring is a prerequisite for continuous learning, which is the goal of action research. The evaluation of the current collaboration status in each cycle via the NAM enabled constant quantitative monitoring, which provided a picture of the changes in network structure after the respective actions were implemented.

3.6. Lessons learned from the network assessment method

The first action research cycle was evaluated by building on a set of questions (Battistella et al., 2015). The first question asks whether the original diagnosis was correct. The NAO reported a lack of strategic guidance regarding the management of network

contacts. A NAM tailored to the specific situation was perceived to be missing. The second question asks whether the taken action was correct. This could be confirmed only in part. The assessment of unleveraged collaboration potential and the definition of clusters provided a vision of what could be achieved and around which foci collaboration could be built. Still, it did not provide concrete guidance for individual network actors on their strategic networking decisions.

The third question addressed whether the action taken overcame the initial problem. The method helped to overcome the problem to a certain degree, while still exhibiting room for improvement. This leads on to the final question of what to feed into the next cycle. From the feedback provided by the network actors, it became clear that more individual guidance was necessary. The NAM provided a vision for the overall network but did not provide orientation for individual network actors on how to work towards this goal.

4. Networking strategy development (cycle 2)

4.1. Key network management

While the first cycle of action research yielded a network management method for the whole network level, the missing guidance on the management of individual network contacts stood out as a major limitation. To counter this limitation, the analysis needs to include the ego level. Therefore, the method was developed further, whilst retaining the whole network level elements from the first cycle. Two steps on the ego network level were added: first, a partner selection for each network actor; second, a selection of the strategies designed to manage the relationships between the selected partners. A method focusing on ego networks by Ojasalo (2004) was identified as a viable extension for the whole network perspective from the first cycle.

Ojasalos' (2004) network management method (Key Network Management, KNM) consists of three steps: (1) identifying a key network, (2) selecting strategies for managing the actors in the key network, and (3) developing and applying operational level methods for managing actors within the key network. KNM is valuable because it provides strategies for individual network actors on how to manage their relationships. It therefore extends the method developed in the first cycle, since it overcomes its major limitation.

4.2. Adaptation of key network management

We modified the KNM to make it compatible with the NAM. First, the set of collaboration partners determined for each actor was defined as a key network. Additionally, each actor was given three different versions of their key network according to the collaboration foci of customer, research and resource collaboration, as introduced in the first research cycle.

Second, strategies were assigned to manage relationships between two actors and not between an actor and a key network. This aligns the method with the assessment carried out in Cycle 1. Thirdly, the collaboration assessment scale of 0–10 to rate collaboration potential was retained, rather than merely differentiating between high and low ability to contribute to certain goals. Finally, the third step to operationalize the assigned strategies was not included in the developed method but left to the network actors to take care of, according to their specific situations.

4.3. Multi level network management

We combined the NAM and KNM into a single method. The value of this combination is that it allows us to set goals on a whole network level (Network Assessment Method), and it simultaneously builds strategy on an ego level (KNM). As it operates on the different levels of network management, the combined method has been termed Multi-Level Network Management (MLNM).

MLNM has six steps. The first four are based on the Network Assessment Method and address the whole network level including the groups, whereas steps five and six are constituted in combination with KNM and address the ego network level. The second cycle was started in the same manner as the first one. By evaluating the questionnaire, a view on the current and potential future network is possible: the collaboration gap was defined as the difference between the two, and the respective clusters were refined. The execution of these first four steps built the foundation for steps five and six of the MLNM.

In a fifth step, each actor's key actors with whom to partner were defined. The rating of mutual collaboration potential was used as the selection criterion for the key actors of the network. Only if both actors perceived a collaboration potential of at least 2 with each other the actors were included as key partners. Thus, each network actor was given a set of key actors according to the identified set of collaboration opportunities.

In a sixth step, strategies to manage those key actors were defined. Every network actor received networking strategies for every other actor in the network. The strategies were adopted from the KNM and assigned according to the rating of collaboration potential. Values of 0 or 1 were disregarded as being too low to consider collaboration. Values of 2–5 were defined as low collaboration potential and values of 6–10 as high collaboration potential. Fig. 2 displays the six steps of MLNM.

The result of MLNM is a set of deliverables. Starting with the whole network level, there are network structure measures that provide an overview of the current and potential future network status as well as the gap between them (see Table 3). Because the overall network values were obtained by calculating the average ratings for each connection of the three different focus networks, they differ from the average of the overall values derived from the respective values of the different collaboration focus networks. The gap was calculated as the difference between the current status and the future potential.

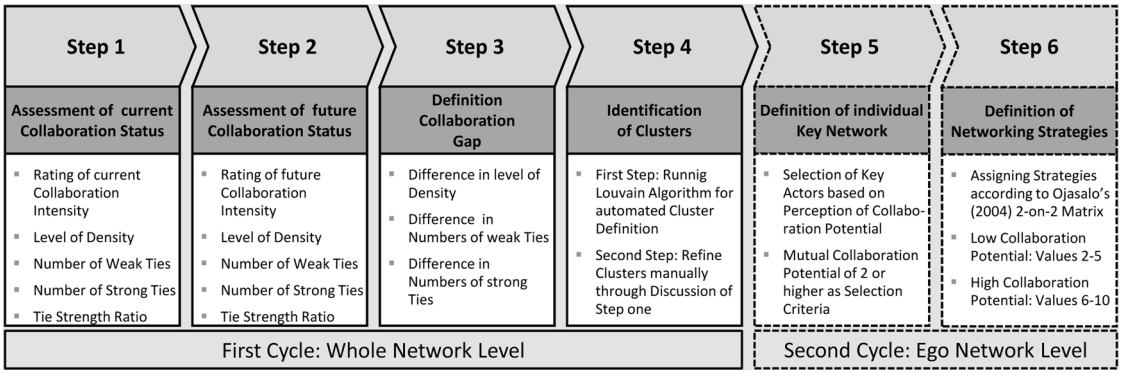


Fig. 2. The six steps of Multi Level Network Management.

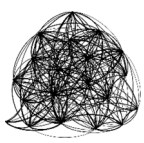
Table 3
Network structure measures, Cycle 1: 18 actors, Cycle 2: 24 actors.

Network Structure Measures of the Current and Future Collaboration Status and GAP												
	Foci of Collaboration	Density			Strong Ties			Weak Ties			Strong Ties/Weak Ties Ratio	
		Current Status	Future potential	GAP	Current Status	Future potential	GAP	Current Status	Future potential	GAP	Current Status	Future potential
Cycle 1	Resource Focus	26%	77%	51%	19	122	103	70	141	71	0.27	0,87
	Customer Focus	19%	81%	62%	14	131	117	50	146	96	0.28	0,90
	Research Focus	19%	78%	59%	14	140	126	51	127	76	0.27	1,10
	Overall Network	**19%**	**76%**	**57%**	**15**	**152**	137	**50**	**109**	**59**	**0.30**	**1,39**
Cycle 2	Resource Focus	19%	74%	55%	27	212	185	83	216	133	0.33	0,98
	Customer Focus	25%	78%	53%	33	198	165	112	253	141	0.29	0,78
	Research Focus	24%	76%	52%	34	208	174	106	229	123	0.32	0,91
	Overall Network	**21%**	**76%**	**55%**	**29**	**229**	200	**95**	**211**	**116**	**0.31**	**1,09**

As the network assessment was carried out for the second time in cycle 2, a comparison with the previous year was possible. Table 3 presents the network structure measures of the network in 2015 and 2016. For all three collaboration foci, a significant increase in weak and strong ties was found, leading to a higher level of density. As strong and weak ties offer different benefits (see Section 2.4), management can draw conclusions from the observed changes. This documents a very positive development of the network, clearly showing intensified collaboration. Given the increased size of the network from 18 to 24 actors, an increase in the density can be rated positively since bigger networks tend to have a lower density due to the increased costs in maintaining ties. Also, the network actor's perception of future collaboration opportunities improved, as is indicated by the higher numbers of potential future strong and weak ties.

Table 4 visualizes the data in the form of network graphs for current status and future potential and the gap between them. The graph of the gap shows the connections that have not yet been established, but may well be established in the future. A more refined analysis could be carried out on the level of the topic clusters.

Table 4
Network graphs of current status and future collaboration potential and of the Gap.

Network Graphs of the Overall Network		
Current Status	Gap	Future Potential
		

The following presents the results for network management on the ego level, which offer guidance to individual network actors. The first result is a collaboration match matrix that provides an overview of the network actor's ratings on perceived collaboration potential. It is based on the input from the questionnaire and contains the values that the respective network actors assigned each other. Table 5 illustrates a collaboration match matrix from six actors. For example, actor 1 ranks collaboration potential with actor 2 very high (a score of 9 out of 10), and actor 2 is also positive about future collaborations with actor 4 (8 out of 10).

Table 5
Collaboration Match Matrix of the dyadic ties for actors 1–6.

	Actor number					
		1	2	3	4	5
Actor number	1					
	2	9/8				
	3	5/7	5/4			
	4	6/5	5/1	6/5		
	5	6/8	4/4	7/5	10/9	
	6	2/5	7/7	2/0	10/7	7/7

Finally, strategies are provided for the network actors via a key actor management portfolio. Such a portfolio provides an overview of the four relationship management strategies suggested by Ojasalo (2004). (1) If an actor is able to contribute to a key network and is also likely to profit from it, the correct strategy would be to invest in this relationship. (2) In the reverse scenario, the relationship should be abandoned. (3) When the actor demonstrates a high capability of contributing to the key network but the key network cannot contribute much substance to the goals of the actor, the strategy would be to develop this relationship, investing in it selectively. (4) In the reverse scenario, the recommended strategy would be to maintain the relationship and manage it for earnings.

Each actor receives a customized portfolio for each collaboration focus. Each portfolio includes all actors that were selected for the respective focal actor's key network. A portfolio's Y axis maps the values that the respective focal actor assigned to partnering actors. The X axis maps the values that the partnering actors assigned to the focal actor. The result is a portfolio of four quadrants, each representing the recommendation of one of Ojasalo's (2004) four strategies. As an example, the Key Actor Management Portfolio of actor 1 for the overall network is provided in Fig. 3 for actors 1 to 6.

Following the Key Actor Management Portfolio, actor 1 should manage his/her contacts as follows. The relationship to actor 3 should be further developed and invested in selectively. The relationship with actor 4 should be maintained and managed for earnings. The relationship with actor 6 should not be developed at the moment. A focus should be placed on relationships with actors 2 and 5. These should be nurtured and invested in heavily.

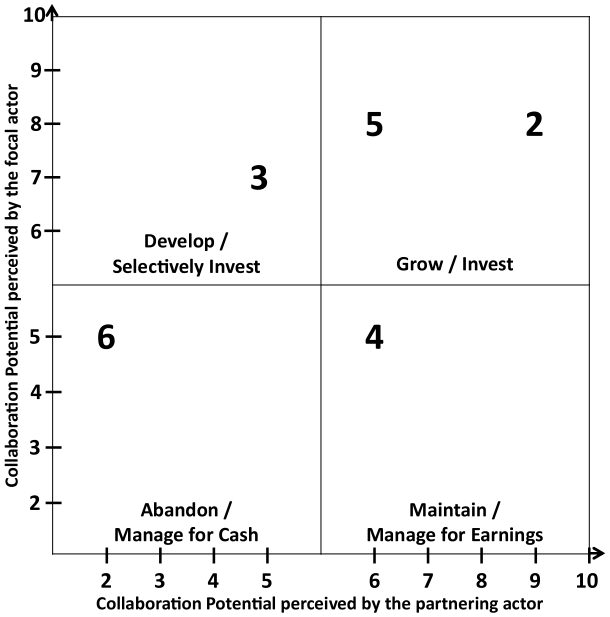


Fig. 3. Key Actor Management Portfolio of Actor 1, own interpretation based on Ojasalo (2004).

4.4. Lessons learned from multi level network management

As a first step in the evaluation of the second cycle of action research, we used the four questions that were applied to the first cycle. The first question of whether the original diagnosis was correct can again be confirmed. The feedback from the network administrative organization indicated that the lack of individual guidance for network actors was perceived as the major problem. Also, the diagnosed need to offer solutions for both the whole network level and the ego level was correct. Providing analysis and strategies for both levels helped network actors take decisions regarding their own relationships, whilst remaining cognizant of the bigger picture.

Furthermore, the second question of whether the action taken was correct could be confirmed in large part. The ego level strategies provided to the network actors created a better basis for their strategic networking decisions. Still, while it was not the goal of the method developed to provide operational guidance on everyday networking, it became apparent that there was a demand for such support. This limits the degree to which the second question can be answered in the affirmative.

The same holds true for the third question on whether the action taken overcame the initial problem. In general, it can also be answered with a 'yes', bearing in mind that the goal to provide strategic guidance was achieved. The feedback from the network administrative organization was very positive in this regard. Still, there was the caveat of the missing operational guidance that cannot be provided by this method. The fourth question concerns what needs to be fed into the next cycle: operational guidance must be provided to manage the network on a day-to-day basis.

5. Discussion

The goal of the research was to develop an actionable management method tailored to the specific demands of innovation networks. Action research was chosen as the research approach.

The goal of the first cycle of the action research was to define opportunities for collaboration from the whole network perspective and, thereby, increase the number of network ties. Since the network consisted of young organizations, establishing more connections between the network actors was considered beneficial (Shan et al., 1994; Ahuja, 2000; Owen-Smith and Powell, 2004), even though other researchers stress that increasing the amount of inter-organizational network ties will erode the benefits of collaboration at some point due to maintenance cost (Wadhwa and Kotha, 2006; Rothaermel and Alexandre, 2009).

There are two arguments in favor of encouraging an increase in the number of ties in young and developing inter-organizational networks. First, the struggle of young organizations for resources and growth is hindered by what Baum and Oliver (1992) call the liability of unconnectedness (Partanen et al., 2014). Young organizations can overcome this liability by becoming involved in networks through which they can acquire essential resources (Partanen et al., 2014). Such networks are of special importance to technology-based innovative organizations (Propris, 2002; Neergaard, 2005; Pitt et al., 2006), as in the case of the innovation network referred to here.

Second, an increase in collaborative ties does not have to be promoted per se as an end in itself. Rather, the approach developed suggests that ties are established between actors only if specific collaboration opportunities are provided. Therefore, this approach is not likely to generate maintenance costs that exceed the benefits derived from inter-organizational ties. Thus, the approach is expected to contribute to better networking between all actors and, thus, to fuel joint innovation.

The goal of the second cycle of action research was to extend the methodology developed and derive concrete actions for actors on the ego level. Application to an innovation network has demonstrated that Multi Level Network Management (MLNM) is actionable. The evaluation cycles of action research have proven useful to improve the method. Applying MLNM repeatedly offers not only the chance of constant improvement based on feedback but also of monitoring the development of a network and controlling the progress of its development towards the future potential desired.

The results from the second cycle of action research have shown a significant growth in the intensity of the collaboration. All network measures confirmed that more connections were established. Hence, the goal of enabling further collaboration within the innovation network was achieved.

Beyond these considerations, MLNM may be judged in the light of the functions of network management that Sydow and Duschek (2013) defined. The first function refers to the selection of suitable actors. MLNM can provide very concrete guidance on this matter through the assessment methodology and the criteria defined for actor selection.

The second function refers to the regulation of network activities and relationships. While MLNM is not designed to regulate concrete activities, it is very much suitable for regulating relationships. The ego level strategies that were derived from Ojasalo (2004) provide exact advice on whether to maintain, intensify or abandon a certain relationship. Hence, the first two functions of network management are covered by MLNM to a convincing degree.

The third function that Sydow and Duschek (2013) address is the allocation of resources. In this case, MLNM can help only in the sense that it provides guidance on deciding to whom to allocate more resources and to whom less. This may apply to resources such as time or shared machinery, which are best shared with partners associated with high collaboration potential.

The last function of network management in this context is the economic evaluation of inter-organizational relationships. This points to a major limitation of MLNM. While it is a very practical method to monitor networks and provide strategies on both whole and ego network levels, it lacks an evaluation mechanism. Hence, no feedback on whether the actions taken actually lead to further innovation can be obtained. This is another important aspect that future research could well focus upon. However, when repeated over time, MLNM can be used to monitor the development of a network and, therefore, validate whether collaboration has been intensified over time or not.

6. Conclusion: main contributions and limitations

The main contribution to the scientific literature relates to the combination of methods used to manage networks on the ego perspective and the whole network perspective. Any network that strives to integrate the ego level and the whole network perspectives into its management of output and evolution is a suitable research context for work on the interdependencies between ego-level and whole-network-level management. For example, our particular case is one of orchestration (Baum et al., 2003; Dhanaraj and Parkhe, 2006; Ahuja et al., 2012; Zaheer and Soda, 2009), where network actors are involved in management of the process network. Here, questions of power and interdependency can be addressed. Should research be able to compare two levels of managed networks, and should this comparison suggest conditions for a natural experiment in which questions about the level and the interdependencies between the levels that exert greatest influence on innovation output can be addressed.

The research limitations in our paper relate to the contextualization of our research and hence our findings. While our study pinpoints certain benefits of action research, its specific results may be limited to particular contexts. First, although numerous innovation networks with a NAO exist, the generalizability to innovation networks without a NAO may be limited in that the MLNM requires management effort, e.g. in collecting data, managing doubts, evaluating the data, and executing the workshops. Applying the approach to other networks requires a certain degree of capacity that the network management must have – a neutral position or organization is preferable for the execution. Second, in our context, the innovation network was in its constituent phase where connections had to be established. Actors in older, more rigid networks may resist the implications for change that may result from a MLNM process, or the network evolution may be impacted by other tendencies to inertia (Gulati and Gargiulo, 1999; Zaheer and Soda, 2009). Furthermore, the network that we investigated was a mandated network (Baum et al., 2003; Zaheer and Soda, 2009; Ahuja et al., 2012; Popp et al., 2013). This is to say there was external interest and power in managing the network, and the establishment of the NAO was mandated.

The main contribution to practitioners is the development of an actionable method that gives network administrators (here, the NAO), a tool to assess current collaboration in the network and to identify future collaboration potential. Also, the method produces practical conclusions for each actor, leading to concrete implications on the operational level.

The MLNM may also have practical limitations in that it addresses network management from the perspective of the NAO, and not from the perspective of individual actors. Even though tools such as the Key Actor Management Portfolio (Fig. 1) already address individual actors, the management of their relationships needs to be supported with other tools. Second, while the MLNM is free to include various performance metrics for evaluation purposes, the NAO needs to make an explicit choice between performance indicators such as number of projects in collaboration, patents in collaboration, and collaborative publications. Third, the MLNM tends to address the collaboration potential between existing partners in the sense that a list of network actors forms the starting point for network analysis in the MLNM. While, in principle, new potential partners may be part of the MLNM effort too, potential partners on the periphery may be neglected despite contributing to innovation performance (Gulati et al., 2012; Uzzi and Spiro, 2005;).

These limitations notwithstanding, MLNM is a promising method for the management of innovation networks. Its execution demonstrates its feasibility, and the positive feedback from the NAO underlines its value. Indeed, the evaluation of the method also indicates future research potential. While the method appears to be suitable for increasing the innovation output of inter-organizational networks, an evaluation mechanism must be developed to further validate this proposition. Future action research may focus on ways to provide even deeper orientation on an operational level.

Acknowledgements

Proofreading through Alan Anderson, Kasteelstraat 1A, 3890 Jeuk Gingelom, Belgium. There has been no significant financial support for this work that could have influenced its outcome; this research did not receive any specific grant from funding agencies in the public, commercial, or non-profit sectors. The research and the development of the presented method has been conducted in the scope of projects at the Fraunhofer Institute for Production Systems and Design Technology. Initial results have been presented at the European Conference of Innovation and Entrepreneurship 2016. The corresponding author, Jan-Patrick Cap, is working on his dissertation. His research focuses upon topics related to this publication.

References

Ahuja, G., 2000. Collaboration networks, structural holes, and innovation: a longitudinal study. Adm. Sci. Q. 45 (3), 425–455.
Ahuja, G., Soda, G., Zaheer, A., 2012. The genesis and dynamics of organizational networks. Organ. Sci. 23 (2), 434–448.
Aynaud, T., Guillaume, J.-L., 2011. Multi-step Community detection and hierarchical time segmentation in evolving networks. 5th SNA-KDD Workshop.
Bastian, M., Heymann, S., Jacomy, M., 2009. Gephi: an open source software for exploring and manipulating networks. ICWSM 8, 361–362.
Battistella, C., Toni, A.Fde, Pillon, R., 2015. The extended map methodology: technology roadmapping for SMES clusters. J. Eng. Technol. Manage. 27 (38), 1–23.
Baum, J.A.C., Oliver, C., 1992. Institutional embeddedness and the dynamics of organizational populations. Am. Sociol. Rev. 57 (4), 540–559.
Baum, J.A.C., Shipilov, A.V., Rowley, T.J., 2003. Where do small worlds come from? Ind. Corp. Change 12 (4), 697–725.
Becker, T., Dammer, I., Howaldt, J., Loose, A., 2011. Netzwerkmanagement: Mit Kooperation zum Unternehmenserfolg (SpringerLink : Bücher). Springer-Verlag Berlin Heidelberg, Berlin, Heidelberg.
Bogenstahl, C., 2012. Management Von Netzwerken: Eine Analyse Der Gestaltung Interorganisationaler Leistungsaustauschbeziehungen. Springer Gabler, Wiesbaden.
Borgatti, S.P., Foster, P.C., 2003. The network paradigm in organizational research: a review and typology. J. Manage. 29 (6), 991–1013.
Capaldo, A., 2007. Network structure and innovation: the leveraging of a dual network as a distinctive relational capability. Strateg. Manage. J. 28 (6), 585–608.
Capdevila, I., 2017. A typology of localized spaces of collaborative innovation. In: van Ham, M., Reuschke, D., Kleinhans, R., Mason, C.M., Syrett, S. (Eds.), Entrepreneurial Neighbourhoods: Towards an Understanding of the Economies of Neighbourhoods and Communities. Edward Elgar Publishing, Cheltenham, UK, Northampton, MA, pp. 80–97 Entrepreneurship, space and place.

Corral de Zubielqui, G., Jones, J., Statsenko, L., 2016. Managing innovation networks for knowledge mobility and appropriability: a complexity perspective. Entrep. Res. J. 6 (380). https://doi.org/10.1515/erj-2015-0016. 2016.
Coughlan, P., Coghlan, D., 2002. Action research for operations management. Int. J. Oper. Prod. Manage. 22 (2), 220–240.
Dhanaraj, C., Parkhe, A., 2006. Orchestrating innovation networks. Acad. Manage. Rev. 31 (3), 659–669.
Duschek, S., 2002. Innovation in Netzwerken: Renten-Relationen-Regeln. Springer-Verlag.
EARTO, 2016. About RTOs. http://www.earto.eu/about-rtos.html.
Elfring, T., Hulsink, W., 2003. Networks in entrepreneurship: the case of high-technology firms. Small Bus. Econ. 21 (4), 409–422.
Ford, D., Gadde, L.-E., Håkansson, H., Snehota, I., 2011. Managing Business Relationships, 3rd ed. Wiley, Chichester.
Friese, M., 1998. Kooperation als Wettbewerbsstrategie für Dienstleistungsunternehmen. Deutscher Universitäts-Verlag, Wiesbaden.
Goerzen, A., 2005. Managing alliance networks: emerging practices of multinational corporations. Acad. Manage. Exec. 19 (2), 94–107.
Granovetter, M.S., 1973. The strength of weak ties. Am. J. Sociol. 78 (6), 1360–1380.
Gulati, R., Gargiulo, M., 1999. Where do interorganizational networks come from? Am. J. Sociol. 104 (5), 1439–1493.
Gulati, R., Puranam, P., Tushman, M., 2012. Meta-organization design: rethinking design in interorganizational and community contexts. Strateg. Manage. J. 33, 571–586. https://doi.org/10.1002/smj.1975. (2012).
Haritz, A., 2000. Innovationsnetzwerke: Ein systemorientierter Ansatz. Springer, Wiesbaden.
Huuskonen, A., Kourula, A., 2012. Network management: a review of an emerging cross-disciplinary field. 28th IMP-Conference in Rome.
Jacomy, M., Venturini, T., Heymann, S., Bastian, M., 2014. ForceAtlas2, a continuous graph layout algorithm for handy network visualization designed for the Gephi software. PLoS One 9, e98679. https://doi.org/10.1371/journal.pone.0098679. (2014).
Jansen, D., 2006. Einführung in die Netzwerkanalyse: Grundlagen, Methoden, Forschungsbeispiele, 3rd ed. VS Verlag für Sozialwissenschaften, Wiesbaden, s.l.
John, G., Reve, T., 1982. The reliability and validity of key informant data from dyadic relationships in marketing channels. J. Mark. Res. 19 (4), 517.
Jüttner, U., Schlange, L.E., 1996. A network approach to strategy. Int. J. Res. Mark. 13 (5), 479–494.
Keast, R., Hampson, K., 2007. Building constructive innovation networks: role of relationship management. J. Constr. Eng. Manage. 133 (5), 364–373.
Lavie, D., Lechner, C., Singh, H., 2007. The performance implications of timing of entry and involvement in multipartner alliances. Acad. Manage. J. 50 (3), 578–604.
March, J.G., 1991. Exploration and exploitation in organizational learning. Organ. Sci. 2 (1), 71–87.
Mertler, C.A., 2017. Action research: Improving Schools and Empowering Educators. Sage Publications, Thousand Oaks, California.
Möller, K.K., Halinen, A., 1999. Business relationships and networks: managerial challenge of network era. Ind. Mark. Manage. 28 (5), 413–427.
Möller, K., Rajala, A., 2007. Rise of strategic nets - new modes of value creation. Ind. Mark. Manag. 36 (7), 895–908.
Neergaard, H., 2005. Networking activities in technology-based entrepreneurial teams. Int. Small Bus. J. 23 (3), 257–278.
Nooteboom, B., Gilsing, V.A., 2005.). Density and Strength of Ties in Innovation Networks: a Competence and Governance View. Tilburg University, Center for Economic Research Discussion Paper(40).
Nooteboom, B., van Haverbeke, W., Duysters, G., Gilsing, V., van den Oord, Ad., 2007. Optimal cognitive distance and absorptive capacity. Res. Policy 36 (7), 1016–1034.
OECD, 2005. Oslo Manual: the Measurement of Scientific and Technological Activities. Proposed Guidelines for Collecting and Interpreting Innovation Data.
OECD, 2011. Actor Brief on Public Research Organizations. http://www.oecd.org/innovation/policyplatform/48136051.pdf.
Ojasalo, J., 2004. Key network management. Ind. Mark. Manage. 33 (3), 195–205.
Ojasalo, J., 2008. Management of innovation networks: a case study of different approaches. Eur. J. Innov. Manage. 11 (1), 51–86.
Owen-Smith, J., Powell, W.W., 2004. Knowledge networks as channels and conduits: the effects of spillovers in the Boston biotechnology community. Organ. Sci. 15 (1), 5–21.
Partanen, J., Chetty, S.K., Rajala, A., 2014. Innovation types and network relationships. Entrep. Theory Pract. 38 (5), 1027–1055.
Petry, T., 2006. Netzwerkstrategie: Kern eines integrierten Managements von Unternehmungsnetzwerken, 1st ed. Dt. Univ.-Verl, Wiesbaden Strategische Unternehmensführung).
Phelps, C., Heidl, R., Wadhwa, A., 2012. Knowledge, networks, and knowledge networks a review and research agenda. J. Manage. 38 (4), 1115–1166.
Pitt, L., van der Merwe, Rian, Berthon, P., Salehi-Sangari, E., Caruana, A., 2006. Global alliance networks: a comparison of biotech SMEs in Sweden and Australia. Ind. Mark. Manage. 35 (5), 600–610.
Popp, J.K., MacKean, G., Casebeer, A., Milward, H.B., Lindstrom, R., 2013. Inter-organizational Networks: a Critical Review of the Literature to Inform Practice.
Propris, L.D., 2002. Types of innovation and inter-firm co-operation. Entrep. Reg. Dev. 14 (4), 337–353.
Provan, K.G., Fish, A., Sydow, J., 2007. Interorganizational networks at the network level: a review of the empirical literature on whole networks. J. Manage. 33 (3), 479–516.
Raesfeld, Avon, Geurts, P., Jansen, M., 2012. When is a network a nexus for innovation? A study of public nanotechnology R&D projects in the Netherlands. Ind. Mark. Manag. 41 (5), 752–758.
Rothaermel, F.T., Alexandre, M.T., 2009. Ambidexterity in technology sourcing: the moderating role of absorptive capacity. Organ. Sci. 20 (4), 759–780.
Rowell, L.L., Bruce, C.D., Shosh, J.M., Riel, M.M. (Eds.), 2017. The Palgrave International Handbook of Action Research. Palgrave Macmillan, New York.
Ruokonen, M., Nummela, N., Puumalainen, K., Saarenketo, S., 2006. Network management–the key to the successful rapid internationalisation of the small software firm? Int. J. Entrep. Innov. Manage. 6 (6), 554–572.
Sampson, R.C., 2007. R&D alliances and firm performance: the impact of technological diversity and alliance organization on innovation. Acad. Manage. J. 50 (2), 364–386.
Schilling, M.A., Phelps, C.C., 2007. Interfirm collaboration networks: the impact of large-scale network structure on firm innovation. Manage. Sci. 53 (7), 1113–1126.
Shan, W., Walker, G., Kogut, B., 1994. Interfirm cooperation and startup innovation in the biotechnology industry. Strateg. Manage. J. 15 (5), 387–394.
Snehota, I., Hakansson, H., 1995. Developing Relationships in Business Networks. Routledge, London.
Sydow, J. (Ed.), 2010. Management von Netzwerkorganisationen - Beiträge aus der "Managementforschung", 5th ed. Gabler, Wiesbaden.
Sydow, J., Duschek, S. (Eds.), 2013. Netzwerkzeuge: Tools Für Das Netzwerkmanagement. Springer Gabler, Wiesbaden.
Tikkanen, J., Renko, M., 2006. Developing innovation networks–the art of interorganisational collaboration in high-technology innovation. Int. J. Entrep. Innov. Manag. 6 (6), 573–590.
Tripp, D., 2005. Action research: a methodological introduction. Educ. E Pesqui. 31 (3), 443–466.
Uzzi, B., 1996. The sources and consequences of embeddedness for the economic performance of organizations: the network effect. Am. Sociol. Rev. 61 (4), 674–698.
Uzzi, B., Lancaster, R., 2003. Relational embeddedness and learning: the case of bank loan managers and their clients. Manage. Sci. 49 (4), 383–399.
Uzzi, B., Spiro, J., 2005. Collaboration and creativity: the small world problem1. Am. J. Sociol. 111 (2), 447–504.
Wadhwa, A., Kotha, S., 2006. Knowledge creation through external venturing: evidence from the telecommunications equipment manufacturing industry. Acad. Manage. J. 49 (4), 819–835.
Witt, P., 2004. Entrepreneurs' networks and the success of start-ups. Entrep. Reg. Dev. 16 (5), 391–412.
Zaheer, A., Soda, G., 2009. Network evolution: the origins of structural holes. Adm. Sci. Q. 54 (1), 1–31.
Zaheer, A., Gözübüyük, R., Milanov, H., 2010. It's the connections: the network perspective in interorganizational research. Acad. Manage. Perspect. 24 (1), 62–77.