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Brainport Eindhoven: born from crisis - 25 years as a Triple Helix Governed Ecosystem

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Abstract

Various researchers have called for research into positive examples of successful TripleHelix-governed ecosystems. TripleHelix collaborations are seen as the solution to tackle the current 'wicked problems' of society. Researchers are encouraged to enhance our understanding of governing inter-organizational collaborations (ecosystems) in the context of university-industry-government (Triple Helix) relations. In this paper we therefore describe a case study of the Brainport Eindhoven ecosystem in the Netherlands which embodies a triple helix organization. We go on to show how the regional governmental structure (Brainport Foundation and Brainport Development), on the one hand, stabilizes at a strategic level and, on the other, gives flexibility at the tactical and operational level. This leads to the transfer of knowledge, and to innovation and change within the network.

Keywords: Governance, Crisis, Intervention, Triple Helix, Quadruple Helix, Multiple Helix, Ecosystem, Network, Innovation and Change, Monitoring.

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1 Introduction

All over the world, governments, leading industries, universities, and private institutions are trying to catch-up with successful entrepreneurial ecosystems. In many cases, the success stories of regions like Silicon Valley are taken as a reference point and 'copy-pasted' to different regions and countries; with Singapore and China as prime examples (Etzkowitz & Klofsten, 2005; Pique, Berbegal-Mirabent, & Etzkowitz, 2018). In most of these cases and sometimes after years of hard work, significant financial investments, and somewhat disappointing outcomes it must be concluded that an innovation ecosystem cannot be copied that easily. Instead, it needs to be tailored to the specific origin, situation and conditions of the 'adopting' region or industry. Moreover, previous research suggests that ecosystems emerge from existing networks, long-standing relationships and interactions within these networks. As such, these can hardly be 'designed' and 'formally created' to be operational and successful in the short term (Provan, Fish, & Sydow, 2007). Regional networks are less stable and structured compared to institutions. They evolve over time, both because they are influenced by external economic or social developments and also due to interventions by key players and important stakeholders (Van Aken, Hop, & Post, 1998).

Within a triple helix, the cooperation between different parties (e.g. government, industry and academia) is a vital condition for economic and societal successes; providing a source of innovation on a regional, national and global level. Not only economic growth but also social and technological development must benefit all stakeholders within the network. This collaboration in (triple-helix) networks is often used as a solution to society's so-called "wicked problems"[1] (e.g. the future of mobility, heat stress in the city, the energy transition, but also the problems regarding human capital in the region). However, the evolution of strong entrepreneurial ecosystems, organized on a triple-helix basis, is still underexplored (Etzkowitz & Klofsten, 2005). In this sense, we define a 'strong' entrepreneurial ecosystem as one in which outcomes (economic, societal) are beneficial for all stakeholders in the region.

While the configuration and success of an existing role-model ecosystem (like Silicon Valley) cannot be copied to another country, region, or industry, that does not mean that certain elements cannot be transferred to other initiatives. Or that there are no opportunities to benefit from lessons learned and best practices. Various researchers (Ferlie, Fitzgerald, Wood, & Hawkins, 2005; Turrini, Cristofoli, Frosini, & Nasi, 2010) claim that there is a need for research into the governance and processes of structured networks, wherein triple-helix collaborations lead to the transfer of knowledge, innovation and change within the network.

This paper aims to highlight and analyze the potential of a structured triple-helix network in the Netherlands. Brainport Eindhoven has a long and rich track record in promoting knowledge diffusion and innovation. It is considered to be effective in bridging social and cognitive boundaries (Ferlie et al., 2005) that are seen as constraints within triple-helix collaborations. We analyze the governance and collaboration mechanisms and preconditions of Brainport Eindhoven, by describing the evolution of its triple-helix ecosystem; starting in the 1990's through to today's transition into a multiple-helix and entrepreneurial ecosystem (Gouvea, Kassicieh, & Montoya, 2013; Stam, 2015). Brainport Eindhoven has received critical acclaim, from all over the world, as Europe's leading region in technological innovation. Amongst the many international awards Brainport Eindhoven has received throughout the years, there is one that stands out: being voted the smartest region in the world, by the international think tank Intelligent Communities Forum (ICF), in New York on June 3 2011 (Horsten, 2016; ICF, 2015).

First, we explore the current understanding within the literature about innovative networks, which are nowadays also seen as ecosystems. This includes consideration of related governance and collaboration mechanisms, to gain a fuller understanding of the entrepreneurial ecosystem, and its continuing development, together with the role that governance plays in network effectiveness, by intervening into the system to overcome crisis situations. Secondly, we describe our problem statement, research questions and methodology. Thirdly, we present the findings of our research, including a historic overview of the Brainport Eindhoven ecosystem. We then continue with our conclusions and implications for theory and practice, before finally describing potential pathways for further research.

1. The concept of so-called 'wicked problems' is rarely defined in the literature and there is no consensus on its theoretical underpinnings nor its utility for research. The first outline of 'wicked problems' refer to "social system problems which are ill-formulated, where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing. The adjective 'wicked' is supposed to describe the mischievous and even evil quality of these problems, where proposed 'solutions' often turn out to be worse than the symptoms." (Lönngren & van Poeck, 2021, p. 1).

2 Innovative ecosystems, networks and mechanisms

First, we start with insights from literature about innovative networks and how governance is organized within these networks. Secondly, we describe how these innovative networks develop over time towards a broader concept, which is nowadays called ecosystems. In this section, we describe ecosystem development and how crisis impacts upon the partnerships, collaboration and governance structures. Finally, we draw on literature relating to interventions in ecosystems.

2.1 Innovative networks

The specific term "innovative networks" requires some explanation, because it combines two concepts that have many connotations in literature. Crossan and Apaydin (2010, p. 1164) mention that they could not find an *"overarching framework of innovation determinants"* in their literature review. They refer to five generations of innovation, beginning with the traditional technology push at the beginning of the 1950s and ending with the networking models of open innovation in the 1990s. Tidd and Bessant (2018, p. 264) mention 16 different types of innovation networks, which can be situated inside, outside or in-between different organizations. This suggests that there is no common understanding about innovative networks in the literature. Besides consideration of these diverse types of network, the innovation process (i.e. how collaboration works within the network) is also discussed in the literature. Although the traditional innovation process is often depicted as a linear path from initial idea towards successful innovation, it has, in reality, more 'spaghetti-like' trajectories. That is to say, it does not follow a clear form; with participants interacting at different times, about different topics and in different ways. However, the complicated interactions within the network create rich and diverse linkages, in which ideas can flow freely: developing new products and ways of working, or opening up new markets.

These different ways of working together in networks developed into the term 'Triple Helix'. Russell and Smorodinskaya (2018, p. 117) describe the Triple Helix concept as a *"network developing a simultaneous pair-wise collaboration of legally independent actors of at least three institutionally different sectors"* 1) business, 2) knowledge (universities, R&D centers) and 3) public (government or agencies). The goal of these collaborations is mainly perceived as one of solving societies' 'wicked problems', as mentioned above (Torfing, 2012, pp. 1-3).

Crucially, one-sided governmental action is replaced by collaboration between public and private actors, in the form of governance networks. This could be as simple as members of local government, working together with students from a university and small businesses, to develop a new policy for a city. In the definition given above, a Triple Helix is already a 'multi-helix'. However, in the case of Brainport Eindhoven, the concept of 'multi-helix' is similar, and has a quadruple-helix structure. In the quadruple-helix structure, a fourth actor is involved, in the form of the public. In addition to business, government, and the education sector; local citizens are also represented, and take part in the collaboration as well.

Usually, with the progressive development of collaboration inside the network, the number of stakeholders increases over time. Interactions within and across the boundaries of the network make the network's structure more complicated. As Shipilov and Gawer (2020) describe it, there is a differences between networks and ecosystems. For instance, the hierarchical relation and interdependencies of stakeholders and the contractual relations in a market situation of buyer and supplier. Based on research (Van de Ven, Polley, Garud, & Venkataraman, 2007), we define an innovation network, nowadays, as a non-linear dynamic process, in which many stakeholders collaborate on different levels and in a setting that changes over time. The transition from a Triple- to a Multi- or Quadruple Helix network is also discussed later in this paper, and in the case study.

2.2 Governance in innovative networks

Gulati (1998) defines a governance structure as a formal structure, based on contracts, which are mostly used in partnerships or strategic alliances. Despite contractual agreements, partnerships and governance structures *"are influenced by the dilemma between conflict and cooperation which arises in networks because they are made up of organizations that have their own objectives which do not always coincide with those of the network"* (Arranz & Fdez. de Arroyabe, 2007, p. 647).

Besides formal contractual partnerships, numerous studies, like those by Ring and van de Ven (1994) and Gulati (1995), show that innovative networks strongly depend on the degree of interaction, openness and cohesion between the partners. Social structures resulting from prior co-operation in the network are indicative of future partnerships and become a kind of 'template' for further developments of the network. Powell (1987) sees networks as strongly social, with interrelated agents (nodes in a network): such as organizations, institutions, and individuals. The relationships (ties) between these agents are important in developing strong collaboration and governance structures. The strength or weakness of these ties is based on a combination of duration of the relationship, the intimacy or mutual confidence, and reciprocity between activities performed together in the network. Strong ties, often developed over time, also govern a certain behavioral attitude between the nodes (partners) in the network, gradually developing social control mechanisms (Arranz & Fdez. de Arroyabe, 2007).

According to Turrini et al. (2010, p. 530) *"Most research on networks has focused on issues such as network formation, network governance, power and influence in networks and so on"*. Bevir (2012) states that governance refers to all processes of governing: the design, structuring and governing of networks. The control of network governance takes place by coordination through negotiations; creating trust and commitment, and controlling conflicts by administrating meta-governance (Bronneberg, 2018). Van Aken et al. (1998, p. 313) advocate a separation of strategic and operational management of networks: *"The separation of strategic and operational management . . . should prevent trouble in reaching consensus from damaging the operational relations"*.

Provan and Kenis (2007) examine the governance of networks, and describe three basic network forms: 1) shared governance (governing by the network itself, without a separate governance entity); 2) lead organization (one network participant acts as the leading organization); and 3) network administrative organization (in short NAO, in which a separate administrative entity is formed for governing the network and coordinating the network activities). According to Cristofoli and Markovic (2016), it is important to evaluate the governance within a network in the context of its history; the distribution of power; and relationships between the participants within public networks. They find evidence of mixed modes of network governance but were not able to enter an in-depth analysis in the framework of their study (Cristofoli & Markovic, 2016, p. 107).

Turrini et al. (2010) state that the connections between network partners play an important role in influencing and strengthening the internal network stability, as well as influencing network innovation and change. Connections between organizations also enable access to new technologies and more knowledge (Goes & Park, 1997). Provan and Lemaire (2012) conclude that networks need to be relatively stable at the core, while remaining flexible in the periphery.

Long term stability and the success of a network is partly determined by trust (Turrini et al., 2010, p. 44). However, Vangen and Huxham (2003) state that building trust is problematic. Creating trust within networks can be seen as managing risks and minimizing the vulnerability of network activities. Too much conflict can make a network fall apart and too much consensus can result in a decline in the ability to innovate (Enroth, 2011; Milward & Provan, 2006; Provan & Kenis, 2007). Also, external crisis situations will have an impact on trustful relations, and might

affect the sharing of knowledge within the network. Dahler-Larsen (2005) and Ferlie et al. (2005) emphasize the mediating role of the professional in spreading innovation and sharing knowledge. They conclude that some structured network forms help in spreading knowledge and innovations. They go on to ask for further research, to investigate which preconditions and mechanisms are effective in bridging the social and cognitive boundaries, especially where different professions are present in the same organization.

D'Andreta, Marabelli, Newell, Scarbrough, and Swan (2016) build upon the work of Ferlie et al. (2005) by 1) making the connection between network governance structure and the network partners' dominant cognitive frames; and 2) describing how the interplay between dominant frames and social networks impacts upon the collaborative work that supports the network's innovative power. In a network setting, knowledge is widely distributed, and power is established through informal positions in the social network, rather than through hierarchical means. D'Andreta et al. (2016) highlight the distinction between dominant network frames and individual frames, which typically reflect (but are not determined by) a person's functional role. This places greater emphasis on the development of new ties across established professional boundaries *"... the social network provides a social arena in which individuals become aligned with or resist the dominant frame as they 'refine ... a collective interpretation through a process of discussion and argument"* (D'Andreta et al., 2016, p. 310). They show how structural features operate in combination with dominant frames, to affect the possibilities envisaged and the collaborative work undertaken by network members. In doing so, these shape the network's capacity to bring about innovation and change (D'Andreta et al., 2016, pp. 311-312).

Overall, the literature on network governance states that more than just temporary cooperation is a prerequisite for durable relationships within the network. Real development and growth of the network depends on mutual understanding, which involves the development of a common language. This is a cumulative process, in which trust often comes slowly. It is based on informal but powerful social contracts that emphasize openness, communication, foresight, and discipline. This is especially the case in uncertain, high-risk or crisis situations (Rycroft, 2007). Overall, innovative networks evolve over time; they do not only appear at a particular point in time (Ritala & Almpanopoulou, 2017).

2.3 Development from innovative networks to ecosystems

Today, many technological hot spots around the world: e.g. Silicon Valley in the San Francisco Bay area (Garud & Karnoe, 2001), Singapore and Finland (Cornell, INSEAD, & WIPO, 2018), are considered as ecosystems. But what is an ecosystem exactly?

Moore (1993, p. 26) defines an ecosystem as *"an economic community supported by a foundation of interacting organizations and individuals, the organisms of the business world"*. Nowadays, the concept embraces three elements: 1) dynamic, purposive communities; with 2) complex, interlocking relationships that are built on collaboration, trust and co-creation of value and that 3) specialize in the exploitation of a shared set of complementary technologies or competencies (Geertsen & Post, 2016). This makes ecosystems fertile ground for creating new ventures of different types; both giving birth to them and supporting their ongoing performance and development (Zahra & Nambisan, 2011). Russell and Smorodinskaya (2018) define ecosystems as collaboration-type interactions, which emerge at a moment when network actors achieve a certain level of integration in relation to a joint identity, strategy, and goals.

The ecosystem concept is borrowed from biology. There, it refers to the complex set of relationships that exists among the living resources, habitats, and residents of an area, whose functional goal is to maintain an equilibrium-sustaining state (e.g., animals use the same drinking

pool). In fact, humans and businesses gather in ecosystems for this same reason (Geertsen & Post, 2016). *"The presence of (scarce) resources, (natural) sources, (skilled) labor and financial resources explain the emergence of concentrations of economic activity"* (Geertsen & Post, 2016, p. 13).

While nature has plenty of time, and has neither 'masterplan nor schedule' for the development of its ecosystems, we are used to organizing our activities in the economy and society in a structured way, to achieve predefined objectives or ambitions. In the context of societal challenges and economic development, we feel the need to plan, manage and control the development and exploitation of innovation networks. In this process, we must deal with limited resources (time, space, financial, human capital, etc.), to develop a sustainable and self-supporting network. However, it is questionable whether this managerial perspective still holds in a time of volatile, uncertain, complex, and ambiguous change, which is often the situation when we are faced with 'wicked problems' or crises.

Oh, Phillips, Park, and Lee (2016) argue that deliberately designed ecosystems in business and innovation do not actually resemble natural ecosystems and that the innovation ecosystem literature shares theories and concepts with research on national and regional innovation systems. The innovation ecosystem concept is used to describe various empirical types of networks, like firm-led ecosystems, digital platforms, regional innovation ecosystems, university-led ecosystems, and so on.

Other research applies 'the helix concept' with a specific focus on university - industry collaboration (UIC) (Bjerregaard, 2010). In studying UIC, scholars use different perspectives: 1) that of a focal actor, being a university or a single firm (Mahdad, 2016); 2) focusing on the role of intermediary organizations (Kirkels & Duysters, 2010); 3) using a dyadic perspective (De Maeijer, 2020); or 4) applying a multi-stakeholder lens (Albats, 2018). Also, in this dyadic perspective, differences in both worlds (e.g. the UIC) will be reflected in different mindsets, use of language, ways of working, and so on. This might therefore require an intermediate liaison role, to bridge the professional cultures of the organization members (Pieterse, Caniels, & Homan, 2012).

Ritala and Almpanopoulou (2017) state that, although they are open social systems, innovation ecosystems are deliberately designed and evolve over time around a key set of entities; not only at a particular point in time. They suggest that the term innovation ecosystem should ideally be used in respect of systems that focus on innovation activities (goal and purpose); involve the logic of actor interdependence within a particular context (spatial dimension); and address the inherent co-evolution of actors (temporal dimension). Altogether, the innovative ecosystem and the governance structure are gradually developing from a small and manageable setting towards a wide-open and less controllable setting, in which higher goals become relevant for all stakeholders acting within the ecosystem.

The definition of innovative ecosystems as deliberately designed – yet open and evolving – social-economic systems, draws the attention to the purposes, aims and objectives of these multi-stakeholder networks. Aimed at certain results and outcomes, these ecosystems need to be organized, structured, managed and monitored. However, the innovative ecosystems often consist of many heterogeneous actors who act in a parallel manner, generally unpredictably (emergent) and in a self-organizing way. This is in line with the work of Granstrand and Holgersson (2020, p. 3), who define an innovation ecosystem as *"the evolving set of actors, activities, and artifacts, and institutions and relations including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors".* In fact, the overall result of the innovative ecosystem at the macro level arises from the inter-relationship of the actions of many individual actors at the micro level. This is an ongoing, non-linear and flexible process at the

micro (operational) level. From a macro-level (strategic) perspective, the governance structure strives to maintain a linear course, in which the ecosystem behaves successfully over the long term. The effectiveness of the innovative ecosystem is nevertheless a delicate balance between long-term stability and short-term flexibility. It is an open and dynamic 'structure', in which *"macro-level growth patterns emerge nonlinearly out of synergies generated by network interactions of various heterogeneous actors at the micro-level"* (Russell & Smorodinskaya, 2018, p. 124). Such ecosystems are organized as complex networks or business ecosystems (Clarysse, Wright, Bruneel, & Mahajan, 2014). These insights reflect our definition of an innovative ecosystem, as used in this paper.

2.4 Intervening in ecosystems in times of crisis

Ecosystems, whether it be a Triple or Quadruple helix innovative networks, need ongoing attention of all stakeholders to prosper and grow, just like living systems in biology. However, sometimes forces from outside or inside the ecosystem will unbalance the status quo of the network. In a complex world these forces are often the rule rather than the exception based on variability, randomness and uncertainty around us (Taleb, 2012). On a global scale we see different disruptions, such as climate change or economic and political instability. These global disruptions might have an impact on a national or even regional scale. On the national scale a shift in regulations, dependency on specific technology or disruption in supply chain will have a great impact on the stability of the ecosystem (Ramezani & Camarinha-Matos, 2020).

The opposite of the outside forces on an ecosystem are its internal characteristics and the way it responds in response to crises. Based on the work of Taleb (2012) and Ramezani and Camarinha-Matos (2020), different ecosystems might respond in different ways to crises and disruptions. The first type can be labeled as 'fragile', indicating an over-optimized, technology-driven ecosystem, with no built-in responsiveness. A second type, 'robust', indicates that the ecosystem can cope with shocks and remain in a steady state. The third, 'resilient' type of response indicates that the ecosystem can recover and adjust towards a new equilibrium. It shows adaptability and dynamic transformative capabilities (Teece, Pisano, & Shuen, 1997). Finally, the 'antifragility' mode indicates that the ecosystem can absorb the shock and grows from it. Taleb (2012) describes antifragility as a mode to survive in a volatile, uncertain, complex, and ambiguous world.

In this sense, ecosystems can be seen as complex adaptive systems (CAS), in which non-linearity is dominant. Ramezani and Camarinha-Matos (2020) mention that the following capacities are necessary to develop an innovative ecosystem: 1) absorptive coping capacity; 2) adaptive capacity; 3) transformative capacity; and 4) learning capacity. Depending on the intensity of change, from stability to instability or improvement, the learning capacity must increase.

Due to these forces and coping capabilities, ecosystems are always changing to sustain their effectiveness. Therefore, the development of innovative ecosystems requires ongoing attention to the effectiveness and results of the network. For an innovative network, these results are mostly financially driven, with a strong customer focus. The innovation systems of the 1990s were mainly established by national and regional governments, in close cooperation with lead companies (OECD, 1999). The network effectiveness was often based on a producer-centric focus; mostly the lead company and all of the suppliers needed for parts, products and services (Russell & Smorodinskaya, 2018). To improve the effectiveness of the network, both social and technological interventions are needed in the ecosystem, to establish growth for the future.

Turrini et al. (2010, pp. 530-531) have developed a framework that helps to describe and explain network effectiveness. *"Network effectiveness is grounded on two elements: network*

structural characteristics such as interconnectedness and cohesiveness among actors and degree of centralization and network stability which can be seen as a contextual factor that has a moderating effect on network effectiveness. Network integration achieved by having a core central agency enhances the network's overall effectiveness". Provan and Milward (1995, p. 26) also describe the role of stability on network performance yet state that *"stability alone is a necessary but insufficient condition for favorable outcomes"*.

The continuing effectiveness of the ecosystem requires different kinds of interventions, in response to its growing complexity. Russell and Smorodinskaya (2018) differentiate between business networks and triple-helix collaborative networks (e.g., ecosystems for continual innovation). The activities of the triple-helix ecosystem partners are based on joint identity, strategies, responsibilities, and goals. The interventions in this kind of ecosystem are dispersed, agile and based on spontaneous self-organization. Priority is given to continuous improvement within the ecosystem. This means eliminating barriers, overcoming crises, and providing incentives for more collaboration, in ways that will improve cohesion and knowledge-sharing across the network. This often requires interventions which are described by Valente (2012, p. 49) as *"efforts to influence actors [. . .] and accelerate behavior change in order to improve the network performance, and achieve desirable outcomes among individuals, communities, organizations, or populations"*. Mostly new policies, financial incentives and support are strategies used to facilitate the development of the ecosystem and create greater performance. Public managers, business leaders and facilitation institutions are the driving forces; facilitating the development of the ecosystem in ways that are beneficial in addressing specific challenges, and using the existing network structure to spur changes in attitudes and behaviors (Siciliano & Whetsell, 2021). The idea behind the interventions is to get as many actors as possible in the network connected and interacting together; while, at the same time, setting out the strategic direction. This increase of connections and interactions is also visualized by Siciliano and Whetsell (2021, p. 25) in their post-intervention diagram.

As leading actors in the process, the public managers, business leaders and facilitators mentioned above have the dual roles of both participating within the ecosystem and, at the same time, influencing its continuing development. This requires excellent communication; building trusting relationships; engagement with all stakeholders, despite their heterogeneous backgrounds; and influencing skills for propelling new ideas and proposing new ways of organizing together (Donald, 2019). From this perspective, those involved have to create a *"web of interdependent change agents and shape an environment that elicits the behaviors across the ecosystem necessary for transformational change and dynamic interaction"* (Dinwoodie et al., 2014, p. 3). At the same time, these leading actors have the task of introducing systemic disturbances and creating the conditions in structures and processes under which innovation is ongoing within the ecosystem. In this way, the ecosystem might develop from a centralized and multi-clustered web towards one focused on transformational change, in which all nodes gain momentum for transformation across the ecosystem.

The above perspective on ecosystem development and 'intervening' might require complexity thinking, which challenges more traditional (system) thinking. Stacey (2001) mentions that interactions between agents in a complex environment, such as an ecosystem, can be seen as a cause for (disruptive) innovation and adaptation. The need to adapt is obvious, but the ability to focus on the right things at the right moment is underdeveloped (Eoyang, 2011). This explains the difference between sustaining stability and identity and adaptation towards the new situation requiring flexibility. Innovation of the ecosystem asks for continuity and at the same time radical change (Kash & Rycroft, 2003).

3 Research objective and method

As mentioned in the Introduction, there is a need for empirical research into the governance and processes of successful ecosystems; and how these influence flexibility, knowledge transfer, collaboration and (dissemination of) innovation. Other researchers (Ferlie et al., 2005; Turrini et al., 2010) have advocated studying the best practices of triple-helix ecosystems that are having a high impact on innovation and change.

This paper is primarily based on an extensive case study of the Brainport Eindhoven ecosystem, including the underlying network governance. For various reasons, this research qualifies as a 'critical and revealing case' (Yin, 2014). Over recent years, the region has received international recognition from, among others, the Intelligent Community Forum; Forbes (*"Eindhoven is hands down the most inventive city in the world"*); Fortune (*"The next Silicon Valley could well be in Eindhoven"*); and Euro Cities *("Eindhoven wins Eurocities award for best regional cooperation"*) (Horsten, 2016, p. 23). The region excels in both private and public R&D spending, patent development and global collaboration. It has been identified as a unique technology ecosystem, in that it consists of OEMs, SMEs, suppliers, contract manufacturers, knowledge institutes and government; all working in close cooperation, and having access to physical and fiscal facilities for cost-efficient development.

The main objective of this study is to create a more in-depth understanding of ecosystem development and network governance in times of crisis, by researching a Triple Helix form of governance that emerged from crisis. This can create a better understanding of how innovation ecosystems can be governed requiring balancing between long term strategic stability (e.g. economic growth) and short term operational flexibility (e.g. development of innovative hotspots and start-ups).

In this article we focus on the following research questions:

1) How has the Brainport Eindhoven ecosystem been developing over time, and what crises has it experienced?
2) How did the ecosystem respond to the different crises over time, in terms of strategic stability, operational flexibility, collaboration, and innovation performance?
3) What can be learned about the impact of crisis (and crisis management) on the development of innovation ecosystem?

Until recently, one of the authors worked for the municipality of Eindhoven during the period of the research. Because of this, we had easy access to many former and present stakeholders and formal strategic documents. This gave us a unique opportunity to develop a retrospective view, covering 25 years of experience. This included insights into ecosystem formation and its continued development; the successive governance models; and the impact of this governance on stakeholder behavior.

3.1 Data collection

Research data was collected from three sources. First, a study of formal documents was carried out, to provide a historical overview of the development of Brainport Eindhoven, from the 1990s onwards. These documents (listed in Table 1) were summarized and then merged into a data matrix, for triangulation purposes. This data was then cross-referenced to the data obtained from the other data sources (such as interviews and observations).

The second source of information was insights gained from 17 semi-structured interviews with key stakeholders from Brainport Eindhoven. This was combined with the historical information, obtained from the formal documentation, to give a real-life dimension to the theoretical con-

Table 1. Overview of formal documents

Document name	Author	Reference
Foundation Brainport statutes	Mr R. Th. J. Theunissen	Ref: 2015.0187 RT Amendment of the Foundation Statutes (translated title)
Horizon Program	Program office Horizon	2005 The Horizon Harvest (translated title)
Brainport Navigator	Maas et al.	2004 Brainport Navigator 2013
Brainport 2020	Van Berlo et al.	2011 Top economy, smart society
Governance Brainport 2020	City of Eindhoven	Memo Brainport 2020 established 25-02-2011 RIS Eindhoven (translated title)
Brainport Next Generation	Brainport Development	2015 Brainport Next Generation renewed strategy (translated title)
'Regio envelop'	Brainport Foundation	2018 Proposition Brainport Eindhoven for Regional Envelope (translated title)
National Action Agenda	Brainport; Netherlands; Brabant province	2018 Brainport National Action Agenda (July 2018) (translated title)

cepts from the literature. The interviews, representing 15 hours of recordings and 300 pages of transcripts, were carried out with current and former directors and board members of different organizations. Table 2 provides an overview of the people interviewed during the research period in 2019; including their professional background and formal position in the governance structure. All interviews were recorded, to enable transcriptions to be made afterwards, which were validated by the interviewees. The transcriptions were summarized and, for triangulation purposes, merged into a data matrix that was cross referenced with the formal documents.

Table 2. Overview of interviewees and their relation with Brainport Eindhoven.

Date interview *(dd-mm-yyyy)*	Organization	Function/Role	Relation with Ecosystem
18-09-2018	Eindhoven municipality	Strategic advisor	Strategic advisor Brainport Development
21-03-2019	HAS University of Applied Sciences and LS X-Links Consultancy	Lector and managing director	Former managing director Brainport Development
13-03-2019	Helmond municipality	Mayor	Member Brainport Foundation
26-02-2019	Huijbregts Group	Managing director	Member Brainport Foundation

Date interview *(dd-mm-yyyy)*	**Organization**	**Function/Role**	**Relation with Ecosystem**
22-02-2019	ASML Holding NV	Member of the Board of Management	Member Brainport Foundation
25-02-2019	Philips Electronics Benelux	Chair of the management board	Vice chairman and member Brainport Foundation
04-03-2019	Philips Electronics Benelux	Member of the supervisory board	Former vice chairman Brainport Foundation
06-03-2019	Brabantse Ontwikkeling Maatschappij (BOM)	Team Manager Ecosystem Development	Former vice director Brainport Development
19-02-2019	Technical University Eindhoven	Vice President of the Executive Board	Member supervisory board Brainport Foundation
24-09-2018	Brainport Industries (BI)	Managing director	Brainport Industries
04-03-2019	Eindhoven municipality	Mayor	Chair of Brainport Foundation
06-03-2019	NTS Group	CEO	Member Brainport Foundation
20-02-2019	Fontys University of Applied Sciences	Chair of the management board	Member Brainport Foundation
21-02-2019	Formerly Eindhoven municipality	Former mayor	Former Chair of Brainport Foundation
17-09-2018	Eindhoven municipality	Head of Strategic Department	Management of strategic advising Eindhoven
22-02-2019	Formerly Eindhoven municipality	Former councilor	Former member Brainport Foundation
02-10-2018	Brainport Foundation	Secretary	Brainport Foundation

The main sections of the semi-structured interviews covered questions on 1) stability and buffering instability; 2) trust; 3) conflict and consensus; 4) social and cognitive boundaries and differences; and 5) innovation and change. These concepts have been defined with theoretical support and operationalized for labeling the interview transcripts. However, in this study we also followed an abductive process, because the questions 'may be' useful to move toward plausible explanations (Mantere & Ketokivi, 2013). In this generative process, we created and evaluated the chosen concepts as mentioned above, but were also able to add other plausible 'explanations' when arriving further in the research. Table 3 shows the concepts, the theoretical definitions and operationalization used in the study.

Table 3. Core concepts, definitions, and operationalization

Concept	Definition	Operationalization	Data collection method
Network inner stability	The strength of connections between network partners (Turrini et al., 2010, p. 542).	The ability to build relations between network partners, by negotiation and, if needed, by (re)organizing the structural processes (Turrini et al., 2010, p. 544).	Documents, historical overview, and interviews
Buffering instability and nurturing stability	Interventions that support the network and strengthen the inner stability (Turrini et al., 2010, p. 544).	The ability to reduce tensions between network partners (Turrini et al., 2010, p. 544).	Interviews
Trust	Trust is a perquisite for the formation, durability and collaboration in networks; helping network partners to deal with risks and uncertainty (Vangen & Huxham, 2003, p. 9).	The ability of managers to build trustful relations (Milward & Provan, 2006, p. 21). The following aspects are crucial in building trust and improving relations: transparency; communication; pro-active exchange of information; and realistic and aligned goals (Vangen & Huxham, 2003, p. 9). The network effectiveness will be reduced when trust in network management is low (Turrini et al., 2010, p. 544).	Interviews
Conflict and consensus	The struggle in the network to reach consensus or to handle conflict effectively, in order to reach common goals (Osborne & Brown, 2005, p. 234).	Putting mechanisms in place for dealing with conflict and reaching consensus. Taking decisions that are in favor of the network instead of individuals and/or separate interest groups (Milward & Provan, 2006, p. 21).	Documents, historical overview, and interviews

Concept	Definition	Operationalization	Data collection method
Social and cognitive boundaries	Relatively impermeable borders between different professional cultures (Pieterse et al., 2012), due to differences in professional backgrounds (Ferlie et al., 2005, p. 125).	Technological, cognitive, or social obstacles between different professional groups, due to diverse professions, sciences, organizational settings, or backgrounds (Ferlie et al., 2005, pp. 125-128; Pieterse et al., 2012).	Documents, historical overview, and interviews
Network innovation and change	Change is the gradual improvement of the existing situation; maintaining a continuity with the past. In contrast, innovation involves the introduction of new elements; resulting in a discontinuity with the past (Osborne & Brown, 2005, p. 4).	The ability to create new ways of thinking and doing. Leadership, communication and vision are usually central themes when implementing change (Osborne & Brown, 2005, p. 222). Creating strong ties between organizations improves knowledge sharing offers easy access to new technology; and increases the ability to learn. This lowers the risk for innovation and change within a network (Goes & Park, 1997). Dialogical forms of communication, and balancing consensus and conflict, improves innovation (Enroth, 2011, pp. 10-11; Osborne & Brown, 2005, p. 222).	Documents, historical overview, and interviews

3.2 Secondary data sources

Our secondary source of information is based on present research projects and observations of recent developments[2] in the Brainport Eindhoven ecosystem. For several years, the authors and research group members have been involved in various triple-helix programs and projects in the Brainport Eindhoven region. By participating in these networks, programs and projects, observations have been made about how partners and stakeholders collaborate in practice (e.g. partner trust and conflict handling) and about decision-making processes in a triple-helix context. Our personal experiences in these projects are taken seriously and have been used in two ways. First these sources provide information on how the ecosystem operates in practice and – in some cases – the practical ways in which the governance and key stakeholder involvement cast their shadow over collaboration and innovation. Secondly, this data has been used for triangulation purposes. Table 4, based on Cloutier and Ravasi (2021), is used as secondary source for this study.

This summarizes the involvement in regional programs and projects.

Table 4. Secondary data sources based on projects in the Brainport ecosystem

Period	Domain	Programme / Project	Role
2002-present	Mobility	ATC, AutomotiveCampus, ACE, Smartwayz, Brainport Bereikbaar	Partner
2011-present	Industry	Brainport Industries – various fieldlabs and project	Partner
2011-present	Business & Incubation	Incubator 3+, Bright Move, Braventure, BCE, The Gate, HighTechXL, and other programmes	Partner, Research
2014-present	Culture & Creative Industries	Various organisations and projects	Supervisor, Partner,
2020-present	Built Environment	Brainport Smart District	Partner
2020-present	R&D and Innovation	Eindhoven Engine	Partner, Project member
2015-2020	Education	Brainport International Education	Coordination, Support, Partner
2013-2015	Health	'Slimmer Leven' Challenge	Partner

Combining data from formal documents, stakeholder interviews (primarily focusing on policy and governance issues) and hands-on observations (focusing on the collaboration and knowledge sharing within the ecosystem itself) we developed a multi-level case description. First the strategic level of governance, expressed in policy and vision documents and how those changed over time. Secondly, the elaboration of these documents on a tactical level, as represented in the interviews. The third level became visible in the theses of bachelor students who were working on projects in the innovation hubs. This provided a better understanding of how stability in the core of the ecosystem (governance at policy level) supports flexibility, collaboration, and innovation on the tactical and operational levels of the ecosystem itself.

4 Findings of the case study

In the 19th century, Eindhoven was no more than a collection of villages, inhabited by mainly peasants and their families. It was situated far away from those Dutch and Flemish cities that were dominating economic and social life in those days. The region was not located on major trade routes; and it lacked valuable natural resources like oil, gas or minerals (Horsten, 2016; Lintsen & Thoben, 2009). Whereas the first industrial revolution had its impact on industry and

2. Examples of institutions and innovation hubs in the Brainport region
https://www.brainportindustriescampus.com/en/
https://innovatiehuisdepeel.nl (in Dutch)
https://www.automotivecampus.com/en/home
https://www.midpointbrabant.nl (in Dutch)
https://urbanlivinglabbreda.nl (in Dutch)
https://brainporteindhoven.com

daily life in certain parts of England, Belgium, Germany, and other regions, it completely bypassed the province of North-Brabant and Eindhoven. Why should it be any different? There was nothing of commercial value in the area, other than cheap labor!

In the second half of the 19th century, things began to change. The Eindhoven region slowly took on a more industrial character; providing space for companies that were producing cigars, textiles, matches and other household items. Then, just before the turn of the 20th century, Gerard Philips settled down in the region. Attracted by the availability of cheap labor, and the presence of an abandoned water mill, he started producing incandescent bulbs. The very first Philips factory can still be found in the city center of Eindhoven, where it now functions as a museum of the Philips Company and recent industrial history.

In the 20th century, Philips developed into a global electronics company offering various household appliances (sound and vision, personal care, kitchen appliances, home lighting, and others) and professional equipment (Stirling engine, hospital equipment, integrated circuit board production equipment, public and office lighting). In support of this, Philips employed over 2,400 R&D employees; collaborating on novel technologies that resulted in groundbreaking inventions, patents, and new product launches.

In those days, Philips expanded its activities in the field of employee wellbeing and demonstrated a strong social responsibility for the city and its inhabitants. The company offered services in the fields of housing, education, sports, entertainment, and medical services. As a result, the city of Eindhoven developed into a lively living environment that was much better equipped; having excellent infrastructure, facilities and – above all – a well-educated professional population. At that time, the Philips family already understood the importance of social networks and building strong ties, creating a stable foundation to build on.

Over time, various companies emerged and were spun-off from Philips, its subsidiaries, and surrounding networks. The entrepreneurial climate of the city, together with the availability of highly skilled knowledge workers and craftsmen, also attracted other industrial companies and service businesses. Nowadays, the region excels in various manufacturing industries (high tech systems and materials; semiconductors; health care; automotive; and food systems, etc.)together with corresponding 'enabling technologies' and services (such as ICT, engineering, and logistics). The region also has a strong position in industrial design and the arts.

Today, the Eindhoven region – which in the 2000s adopted the name Brainport, and later Brainport Eindhoven (see below) – is ranked second with regards to its economic contribution to the Dutch economy, and is widely known for R&D and innovation. Throughout the years, different mayors and captains of industry have been asked to present and explain the successes of the Brainport Eindhoven triplehelix ecosystem, all over the world. The international interest in Brainport Eindhoven is clearly indicated by its several awards and titles. Also, in various rankings, Brainport Eindhoven has achieved good scores throughout the years; including a third place for the most creative economy (OECD 2013-2014) and being considered the best place to invest in Europe, after London and Helsinki (Financial Times, 2014).

Many of the businesses and not-for-profit organizations present in the region have a background in the Philips company; or at least a strong connection with Philips as a customer, supplier, or network partner. Even after moving its headquarters to Amsterdam, reformulating its business strategy and divesting itself of non-core activities and assets, Philips maintains its leading role in private R&D, and as a provider of (professional) health care systems and applications. As a result, the Eindhoven region still benefits from the Philips 'DNA' and a 'family feeling' of togetherness.

Over recent decades, the region has had to face several national, international, and internal crises. A graphic overview of these is shown in Figure 1, below. In the remainder of this chapter,

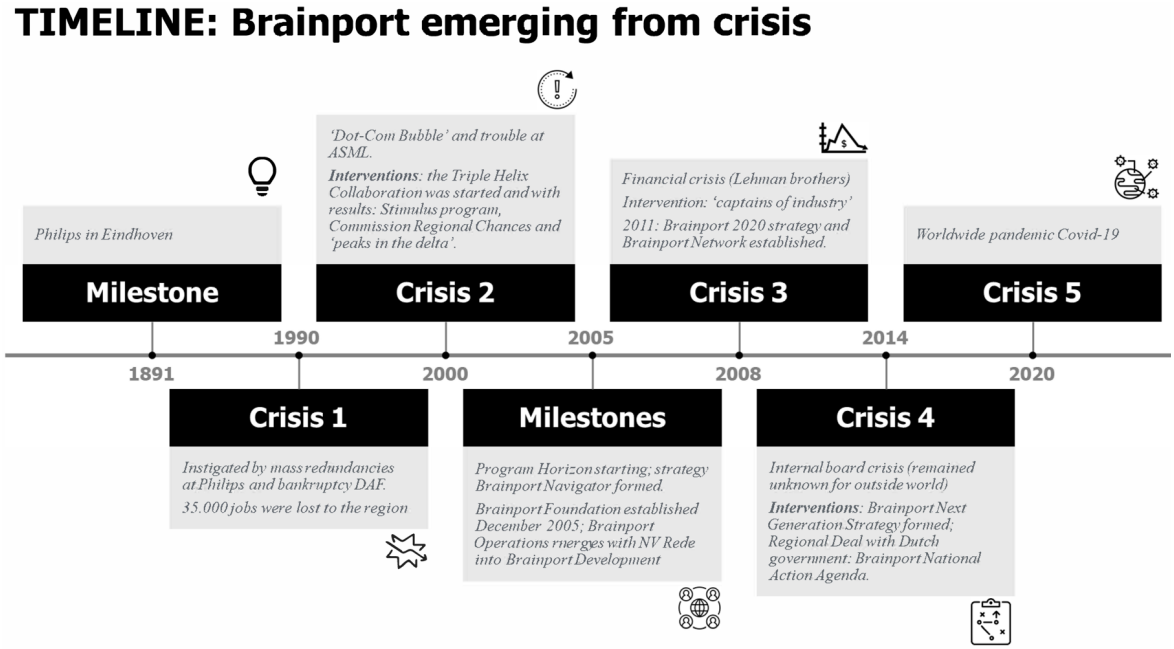

Figure 1. Historical overview of the development of Brainport Eindhoven

we will briefly describe these crises, and discuss what measures have been taken in the triple-helix infrastructure to deal with them.

4.1 Different crisis within the Brainport region

First crisis: A major downturn (1990)

After decades of economic growth and prosperity, the Eindhoven region had to face a major economic and social crisis in the nineties. Philips radically restructured its organization and closed or moved many of its production sites. DAF Trucks, another industry anchor, went bankrupt. As a result of this, many industrial and service suppliers, located in the wider region, suffered from the economic disaster as well. Over 35 thousand employees lost their jobs; causing financial problems to their families and social networks.

In response to these devastating problems, and poor outlook in the mid-Nineties, the Mayor of Eindhoven, the Chancellor of Eindhoven University of Technology and the Chairman of the Association of Industrial Companies decided to join forces. In retrospect, this can be seen as the start of the triple-helix collaboration in the Eindhoven region. All twenty-one municipalities within the region joined in. They also decided to develop a regional fund, dedicated to stimulating new economic activities and innovation.

> "*35,000 jobs were lost at DAF, Philips and the supply chain companies. That was one third of the jobs in the city. What the region could not see at the time, was that these were the first signs of the transformation from a traditional manufacturing economy to a knowledge, creativity, and digital economy. Here lies an important foundation of the triple helix collaboration, born from deep crisis*" (Interview Rob van Gijzel, former Mayor City of Eindhoven).

Second crisis: Dot.com bubble (2000)

The so-called "dot-com bubble" was a stock market crisis caused by a long period of opportunistic speculation in internet companies. It was built on a massive and worldwide growth in the adoption and use of the internet. In the Netherlands, this recession marked the end of a period of overspending and economic growth. It also coincided with the adaptation of the economy to the new European monetary union and the introduction of the euro. This recession also influenced the high-tech industry and ICT companies in the Brainport Eindhoven region. ASML, the world market leader and producer of high-tech lithography machines, had to take measures to reduce production capacity and number of employees. This affected their regional supply base for the second time in a short period of time.

This second crisis within a short time span led to a collaborative initiative supported by various regional business partners of a regional development program, called Horizon, which was co-funded by the European Union (Horizon, 2005). This can be seen as the informal start of structured governance of the Brainport Eindhoven ecosystem. The program's strategy was based on a clear, no-nonsense approach; with actual projects and committed people. These were mainly CEOs, who had the managerial power to get things done and could listen carefully to the requirements of the market. In fact, this can be seen as a business approach to survive the crisis.

> *"Appointing figureheads within projects has been key to success. Because if you ask a CEO from a multinational 'do you want to be the initiator of this project?', And someone like that says yes, then you know that there will be a strong motivator and the chance of success is high"* (interview Elies Lemkes-Straver, Vice-Governor in the Province of Noord-Brabant and former Managing Director Brainport Development).

December 2005 became the formal start of Brainport Foundation, in which captains of industry, policy makers from local government (mayors) and the academic field (board members) gathered periodically to speak about regional development. In addition to this central board, which has representatives from all the triple-helix partners, Brainport Development was also founded as an operational unit that facilitates the triple helix and became responsible for operations and communications in the region.

Third crisis: Financial crisis (2008)

The global financial crisis (or international banking crisis) was a severe worldwide crisis in the financial markets, caused by excessive risk-taking by banks. This was made worse by the bursting of the United States housing bubble; damaging financial institutions across the world and leading to a worldwide recession. In Europe, this coincided with the Greek national debt crisis and the collapse of the Islandic financial system. It also affected Dutch banks and financial institutions (including pension funds) as well as having a negative impact upon national consumption and investment.

The Brainport Foundation took measures to keep R&D employees within the companies and universities, to prevent a regional 'brain-dump'. Employees were supported by being given part-time work without losing income (with part-time unemployment being funded by the government).

> *"To counter the financial crisis in 2008, Brainport Eindhoven CEO's and local government negotiated a knowledge worker scheme from the Dutch national government, this is a typical example of an initiative which originates from within this ecosystem, I call this a Brainport punch"* (interview Jo van Ham, former Executive Vice President of the Board of the Eindhoven University of Technology).

Fourth crisis: Internal crisis (2014)

Some twenty years after the first formal triple-helix collaboration in the Brainport Eindhoven region, the ecosystem faced an institutional changeover in important administrative positions. This led to a discontinuity of board positions in the organization and programs. Most individual members of the management board (Brainport Foundation's inner circle) left. Within the Brainport Foundation, newly appointed members had different perspectives and urged a new strategic course. This resulted in internal disagreements and the surfacing of conflicts of interests. This internal crisis fueled the forming of the Brainport Next Generation strategy (Brainport Development, 2015) , which remains the current way forward. This strategy focuses on five different programs: people, technology, environment, business, and internationalization.

> *"... this was a period of prosperity, which resulted in prominent board members who no longer fulfilled their role within the network. During this period, a new generation of board members took up a position opposing this. This ultimately led to a new strategic vision and changes within the daily management of the foundation"* (Interview Rob van Gijzel, former Mayor City of Eindhoven).

Fifth crisis: COVID-19 (2020)

As we are writing this article, the Brainport Eindhoven region is facing another international crisis, the COVID-19 pandemic. Like most other regions in the world, Brainport Eindhoven is suffering from the economic impact of a lock-down, imposed by the national government, with the aim of controlling the spread of the virus. Since our data collection was completed before the start of this new crisis, we did not collect any interview data relating specifically to this new crisis. However, we can build on secondary data and observations of triple-helix collaboration and interventions aimed at dealing with the pandemic and the effects of the economic lock-down.

In response to the COVID-19 pandemic the Dutch government decided to implement a series of unprecedented economic measures. These were designed to protect people's jobs and livelihoods, as well as seeking to minimize the impact on self-employed people, small and medium-sized enterprises, and major companies.

In addition to this nation-wide support scheme, the triple-helix network partners in Brainport Eindhoven developed additional financial support for start-ups. To qualify for the national aid system, companies were required to prove that they were facing a sudden drop in turnover. Most of the start-ups within Brainport Eindhoven region were unable to do so, as they were hardly making any money at all. These companies nevertheless experienced financial problems due to the COVID-19 crisis. Many investors withdrew or suspended their support, often because they needed these financial resources to keep their own businesses afloat (Vermeer, 2020).

To protect the innovativeness of the Brainport region, Eindhoven University of Technology, Rabobank, Province of North-Brabant, Eindhoven Municipality, ASML, Philips, Brainport Development and others joined forces. They offered financial support to 'healthy' start-ups, so they could come up with a structural solution for their funding. This support prevented innovation coming to a standstill in this region.

> *"... together with the municipality of Eindhoven, the regional government, the province, and the banks, we're looking into creating an emergency solution for these start-ups."* (source

newspaper article interview with Paul van Nunen, Managing Director Brainport Development; Eindhovens Dagblad March 31, 2020).

In response to the COVID-19 crisis, technological boundaries were pushed, and sectoral boundaries crossed, in Brainport Eindhoven, to provide answers to the pandemic. With support of contract manufacturers, Philips was able to ramp up the production of health technology products. Similarly, with the support of the economic development agency of the Brainport Eindhoven region (Brainport Development), and the Ministry of Economic Affairs, another regional health care company, Ventinova Medical, were able to realize a rapid upscale of innovative high-quality ventilation equipment. A third example is Brainport Eindhoven company, Demcon. While it normally developed a single module for respirators, it shifted to building simplified total ventilators for ICUs at breakneck speed. To do this, the company used the strength of the Brainport Eindhoven supply chain, coupled with extensive collaboration with hospitals and health care research partners in the region. Once again, an external crisis proved to be a strong stimulus to joint action: joining forces; prompting open collaboration across traditional borders; and pursuing approaches 'off the beaten track'.

The Brainport innovative ecosystem as we know it today is, and will continue to be, rooted in the strong social ties between all stakeholders that have been created through past collaboration. Especially in times of crisis, this social cohesion – based on trust and cooperation – has been shown to be a driving force in the realization of creative solutions for the benefit of the region.

"*Crisis forced the authorities, educational institutions and the business community within the Eindhoven region to cooperate, these were the 'defining moments' of the network*" (interview Robert Elbrink, Head of Strategic Department City of Eindhoven).

4.2 Today's Governance Brainport Eindhoven

Today, the governance of Brainport Eindhoven triple helix is well balanced, and reflects the various regional stakeholder groups. The current situation provides a stable core in a dynamic social arena. The government is represented by mayors, strategic advisors, and councilors. Not only on the municipal level of the city of Eindhoven, but also on the provincial and national levels, there are strong (political) ties. The academic partners in the Brainport Eindhoven region are well represented by two of its most progressive universities (i.e., Technical University Eindhoven and Fontys University of Applied Sciences). The representatives of the businesses in Brainport Eindhoven are working for big companies that are active in a global market (e.g., ASML, DAF, Philips). These companies are Original Equipment Manufacturers (OEMs) and can only produce their products and services in close cooperation with Small and Medium Enterprises (SMEs). These SMEs are first-, second-, and third-tier suppliers of the OEMs. The chair of Huijbregts Group acts as a representative for other small and medium-sized businesses from the region within Brainport Foundation.

Although the mayor of Eindhoven is the chairman of Brainport Foundation, the entire ecosystem is concerned with more than just the city of Eindhoven. Also, with multiple mayors on the board, the democratic process might work differently and could lead to unexpected outcomes. This means that the 'greater good of the ecosystem' could conflict with the specific agenda(s) of one or more city councils. To shield the mayors within the Foundation, and to enable them to speak freely, a different councilor from within the 'colleges of mayor and aldermen of a city' have Brainport Eindhoven in their portfolio and are responsible for the accountability towards their specific city council. This accountability is demonstrated in the inclusion of a committee note in the annual

strategic plan of Brainport Development. The different city councils can contribute their input to the shareholders' meeting of Brainport Development, through their Alderman who is responsible for the financial portfolio. This 'governance model' works on the strategic (macro) level of the ecosystem and makes it possible to develop a long-term agenda.

> "*The trick to achieving good and successful governance is that it originates naturally and should not be imposed by the government*" (interview John Jorritsma, Mayor City of Eindhoven).

The history of Brainport Eindhoven shows clearly that crises (regional as well as global) led to collaboration within the region, which was later formalized into the Brainport Foundation (with Brainport Development as the operating company). These two core elements of Brainport Eindhoven ecosystem are responsible for the development and execution of a long-term strategic agenda, as already mentioned above. Board members – representing industry, public government, and academia – act as figureheads for all of these programs and are fully in touch with the program teams and project leaders who are responsible for the implementation of the agenda.

> "*The strength of Brainport Eindhoven is that projects are always linked to a regional CEO. In this way you create commitment, feasibility, and realism. Because a CEO only commits himself to a project if he himself also believes that it can become a success, otherwise it would not have been a project to begin with.*" (interview Harry Hendriks, Former CEO Philips Netherlands)

One of the action programs is about the development of Science & Technology Parks (STPs), where industry, industrial and academic research, and education join forces in projects aimed at technology development, technology adoption and innovation. Examples of these STPs are the High-Tech Campus (the number one STP in The Netherlands, based on R&D spending and patent applications); the Automotive Campus; Food Tech Park Brainport; and, recently, Brainport Industries Campus, a state-of-the-art working and learning environment for the next generation in high-tech manufacturing. These, and other STPs in the region, facilitate and develop activities that are aligned with the shared vision and ambitions of the policy makers and core stakeholders of the Brainport Eindhoven ecosystem.

Also, on the meso level, this applies to triple-helix innovation programs, such as 'Slimmer Leven 2020' (translated into Smarter Life 2020) and 'Brainport Smart District' . The former isa program aimed at developing smart solutions and innovation for healthy ageing; while the latter program sets out to co-create a smart living and working district, in which the urban environment is designed in conjunction with a range of new technologies (including those relating to transport, health, energy generation and storage, and circular building). The shared beliefs and ambitions of Brainport Eindhoven seamlessly match the operational activity in these projects.

At the micro level, looking at dyadic collaboration between industry and academia, we encounter partnerships in which participants have been involved with each other, in different configurations, over a period of more than 25 years. In many cases, these relationships and configurations originate from the heyday of Philips corporation. Even today, after many decades of Philips moving factories to other regions in the world and restructuring its core activities, its legacy remains strong. The 'professional offspring' of this R&D and industrial conglomerate experience a strong shared identity; and they are members of a 'social arena' which makes it quite easy to join forces and work together.

> "*During good times you have to build relationships based on common interests, so that help 'is a phone call away' during a crisis*" (interview Hans de Jong, President Philips Netherlands).

Figure 2 presents a stylized view of the social arena in the Brainport Eindhoven ecosystem. At its core is the strategic (macro) level, where the stable triple-helix structure is represented by Brainport Foundation, with support from Brainport Development. At the tactical (meso) level, different programs and projects are linked to the five focal points mentioned in the Brainport Next Generation strategy (Brainport Development, 2015). Finally, the outer circle represents the operational (micro) level. Here, local actors participate in STPs, and work on HTCs in projects, both within their organizations and across organizational borders. At this operational level, the innovation dynamics and forms of cooperation are different; leading to greater flexibility.

The triple-helix stakeholders are not only represented in the central administrative core of the ecosystem but are also involved at program level and in projects. This means they are interconnected throughout the different levels of the Brainport Ecosystem. In many cases, innovation programs are chaired by board members with a triple-helix background, who also act as a liaison between the long-term strategy and executional programs and have employees, who report directly to them, working in the different project teams.

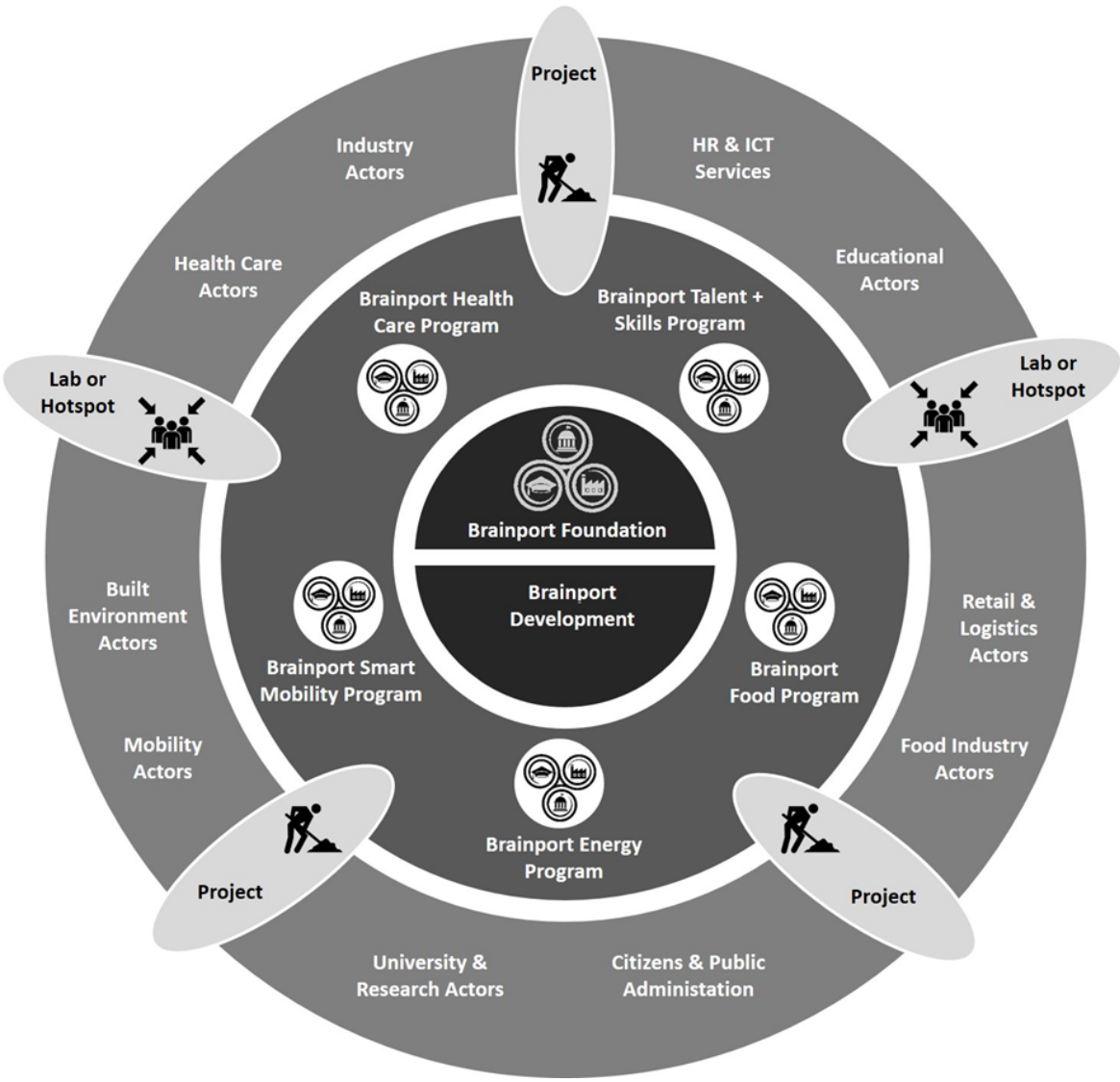

Figure 2. Brainport Eindhoven ecosystem, showing its macro, meso and micro levels

At the macro level, the Brainport Eindhoven core organizations have developed a monitoring tool to measure the progress, outcomes, and impact of its activities. In the current triple-helix ecosystem, monitoring of policies (i.e., strategic long-term programs), interventions and the eventual effects of these are reported yearly. Long-term programs are described in documents such as Brainport Next Generation (Brainport Development, 2015), the Brainport National Action Agenda (Brainport Development, Rijksoverheid, & Provincie Noord-Brabant, 2018) and the Regional Deal (Brainport Development, 2019). These plans are worked out in programs and actions that are themselves interventions within the ecosystem. Steps to ensure the successful delivery of these programs and actions are carried out regularly by program management. Finally, the most measurable effects of these programs and actions are reported at the end of the year. The Brainport monitor (Brainport, 2018; Brainport Development, 2018) is just one example of the ways in which progress in the ecosystem is reported . Alongside the above, programs and projects undertaken in the operational layers of the ecosystem have their own monitoring and progress reports.

> *"You are not part of Brainport Eindhoven for yourself, you do it for the region. The realization that serving the common goal yields more than, just chasing your own interest, is deeply rooted here. Of course, this originated from the mid-90s when there was a deep crisis within the region"* (Interview Frits van Hout, Executive Vice President and Chief Strategy Officer; Member of the Board of Management, ASML Holding NV).

Based on our case study, we recognize the developments in, and evolving character of, innovative ecosystems, as described in the literature. Over 25 years, at times of crisis, the Brainport Eindhoven ecosystem, as it is called nowadays, was subject to deliberate interventions by a small group of leaders from business, government, and research & education. These interventions clearly demonstrate that the governance structure in place is based on strong personal ties and trust amongst members of this small group. They stand behind the vision they formed together and distribute this vision from their positions within the ecosystem.

Figure 2 shows the different levels at which action is taking place. At the macro level, the most tangible results are policies, strategic vision documents and action agendas (see also Table 1). At the meso level, programs are developed within innovation hubs that execute the programs together with relevant stakeholders in Living labs (e.g. Foodpark Veghel is related to the Food program, the Automotive Campus is related to the Smart Mobility program, DIFFER is a research center related to the Energy program, Brightlands Campus is related to the Health program etcetera). At this meso level, intra-and inter- organizational projects are forms of collaboration and can also be levels of analysis (Bogers et al., 2017). The final, micro level shows the different actors that are involved in different forms of collaboration on projects, in Living labs, or at hotspots for innovation (e.g. High Tech Campus, Strijp-S, Brightlands Chemelot Campus).[3]

This way of working in the Brainport ecosystem is clearly boundary-spanning (e.g. crossing organizational borders). It creates collaborative activities that increase interconnectivity between different stakeholders and support ecosystem resilience; while, at the same time, fitting into the strategic agendas of the region. In the end, the goal is to maintain and strengthen a rigorous ecosystem, which can cope with crises both now and into the future.

3. See websites for different hotspots in the Brainport region
https://www.hightechcampus.com/
https://www.brainportindustriescampus.com/en/
https://strijp-s.nl/en/
https://www.brightlands.com/en

4.3 Future: How to develop from a Triple Helix towards a Quadruple Helix?

The following steps within the Brainport Next Generation policy (Brainport Development, 2015, p. 2) are intended to move beyond the current triple-helix arrangement, towards a multiple- or quadruple-helix ecosystem: *"We are therefore moving from triple to multi-helix. No longer just a triangle between government, business, and education. But also involving citizens, customers, consumers, investors, designers, artists and corporations"*. In this quadruple-helix system, the community becomes a vital part of the collaboration within the network. Building on the core concept of open innovation and multiple-helix collaboration, it is important to involve different communities (e.g. the design community), expats and other citizens within the region; connecting them with the Brainport Eindhoven ecosystem. According to the interviewees from the underlying case study (Bronneberg, 2019), this policy change is a difficult one to achieve and hasn't yet been implemented successfully.

This raises the question as to if and how the governance of the ecosystem must adapt to these growing numbers and categories of stakeholders. If the Brainport Eindhoven ecosystem is to transition towards a quadruple-helix ecosystem, the traditional 'managed' governance approaches might become ineffective. According to the interviewees (Bronneberg, 2019), one of the main reasons that Brainport Foundation is successful is because all board members have managerial power within the organizations that they represent (you have 'to matter' within the region). If it is decided that community representation is also needed within the board, the representatives need to be able to operate on the same level as the sitting board members. We therefore advise those who might be considering such developments not to risk destabilizing the working core within the ecosystem. In our opinion it is not necessary to incorporate this quadruple-helix system within Brainport Foundation. In a sense, the community is already represented by the different mayors on the board. However, we do think that the community must be involved, and that they should have an active role in developing the ecosystem to the next level.

In theory, government represents all citizens and social groups in society. As such, the government representatives on the board should be able to address societal and social issues, such as inclusiveness, sustainability and public health. There is, though, a growing need for active participation of citizens and specific social groups in activities at the periphery. Various regional living labs – such as Brainport Smart District and Slimmer Leven 2020 (both mentioned above) – offer a platform for co-creation involving (specific groups of) citizens and representatives. To stimulate these types of civic open innovation, Brainport Foundation explores the possibilities and develops investment policies and facilities to encourage and support additional involvement (including award schemes for citizen involvement).

5 Conclusion and Implementation

This article describes how the Brainport Eindhoven ecosystem has developed over time and what interventions about ecosystem governance have been carried out in response to (external) crises during the last 25 years.

First, Brainport Eindhoven can be seen as a high-tech ecosystem born from crisis. The ecosystem has a triple-helix organization, with a structured network governance at its heart. The case study (Bronneberg, 2019) reveals that collaboration during times of crisis helps to create strong social bonds. The already present 'social arena' (which typifies the Brainport Eindhoven region) further helps the addressing of tensions between individuals or groups; helps to cross social and cognitive boundaries (Ferlie et al., 2005) and helps the framing of the overall purpose of the network, in line with the work of D'Andreta et al. (2016). This shared dominant frame emanates

from within Brainport Foundation, and is avidly supported and communicated with others in the social arena.

The board members become supporters of, and ambassadors for, this dominant frame. Their interventions further support the crossing of social and cognitive boundaries within the network; as well as helping to improve the stable core of Brainport Foundation within the ecosystem. The fact that these boundaries are able to be crossed helps the spread of knowledge and encourages innovation. Strong support for knowledge sharing within living labs, and open innovation within the dominant frame, further enriches the ecosystem. Growing a strong support base is crucial for the transfer of innovation and change. However, this requires time, so continuity within the board helps to strengthen further developments and create a firm support base.

Secondly, the case study demonstrates that a common dominant frame, collaboration born from crisis and built into a common strategy and belief system, connects board members and increases internal stability. This creates a structured and stable core within the heart of a network, which both allows and empowers people and organizations at the periphery to innovate and change. In this way, Brainport Eindhoven confirms the proposition made by Provan and Kenis (2007) that a network form should be stable and flexible at the same time. This creates an ecosystem which allows experimentation and learning from errors; and where people want to work together towards a common goal. This enables Brainport Eindhoven to stay on top of its most stubborn problems.

Thirdly, the Brainport Eindhoven triple-helix collaboration is not the result of a single governance intervention. It originated instead from many coordinated and uncoordinated actions of triple- helix stakeholders within the region. The most obvious coordinated actions were the Stimulus Program (2000), followed by the Horizon program (2005)[4]. In these programs the governance structure was also established; and the local municipality, industries and knowledge institutions started working on the Brainport network. In 2008 different strategies and action agendas were developed. These still coordinate actions today, and provide a stable foundation for further development of the ecosystem. As Figure 1 shows, these coordinated actions were, in the beginning (e.g. between 1990 and 2000), more or less a response to a crisis situation. Captains of industry and the local government saw that the region had become critically dependent on just a few, big, high-tech industries. However, from 2000 up until the current day, the yearly action agendas and regional strategy have become more proactive.

The uncoordinated actions that are facilitated by the ecosystem comprise many big and small projects, some of which were set out in Table 4. However, this is only a small selection of such projects. Other initiatives include the development of a range of start-up programs to stimulate entrepreneurship. Together with financial support and education (as provided, for example, by the Centre for Entrepreneurship) the region develops many hotspots, where people can exchange ideas and collaborate across organizational and sectoral borders. Specific parts of the city, such as Strijp-S and Section C, have been developed as innovation spaces or breeding places for ideas. Previously, these buildings were used by Philips; so this important industrial heritage is preserved. Within this historically important setting, students and companies work together to develop new products, exchange ideas and connect with other initiatives. Although the local government, companies and knowledge institutions together stimulate these interactions, the flow of ideas and initiatives are uncoordinated. The local government promotes this with the ability for partners to start in living labs. Here partners may experiment and innovate within city borders.

Similarly, the High Tech Campus and the Brainport Campus are each a mixture of many different companies, educational institutions and small start-ups. The balance between coordinated

4. These programs represent strategic documents for improving economic development in the Brainport region.

and uncoordinated action is clear. Policies and strategies can be seen as formal interventions. These lead to conditional and coordinated actions that sustain and develop the overall form and functioning of the ecosystem. However, it is the emergence of the many small and uncoordinated actions that eventually determine the success of the ecosystem.

It takes time and effort to develop a successful triple-helix collaboration; and, as this article describes, crises can be helpful in establishing a sense of urgency and the need for collaboration. In particular, crises can strengthen the support for formal agreements and governance interventions. Our case study demonstrates that it can be beneficial to establish a formal governance structure within a flexible ecosystem. However, the 'color locale' and the culture of a region are hard to copy. This suggests that it is not possible to transfer seemingly successful practices from one location to another, without these being 'translated' and adapted to suit the local context.

Fourthly, based on the Brainport Eindhoven case study, we conclude that, once a shared vision, ambition, and strategy has been developed, it is important for the region to be backed and represented by 'local heroes' who have managerial power. Equally importantly, these figureheads should not stay at the 'board table' but need to lead by example; putting in real effort, by leading and managing collaborative projects and programs. We also found that the process of collaborative policy development creates strong bonds. These, in turn, are helpful in periods of crisis. Triple-helix collaboration can therefore also benefit from the presence of a strong 'social arena', with high connectivity and trust between triple-helix stakeholders.

A final remark on the governance of an ecosystem concerns democratic legitimacy. Social responsibility and inclusiveness are becoming more important for the entire Triple Helix, but government and public authorities must address the subjects of democratic legitimacy and inclusiveness on a daily basis. This can cause tension within a triple-helix network; so a structured governance process – as described in the Findings section of this article - might help to ease tensions within the ecosystem.

Other regions with similar ambitions can learn from the experiences of the Brainport Eindhoven triple helix ecosystem and the way it is organized and operates in practice. However, as suggested above, it is not recommended to copy and paste the governance process and developed infrastructure blindly. As mentioned earlier the formal governance, 'social arena', shared beliefs and open collaboration have been developed over a period of 25 years. The journey itself - sometimes characterized by insecurity, hardship, and setbacks but also brotherhood, fellowship, and joint success - is an inseparable element of the development process.

6 Future Research and limitations

As described in the Findings section, the Brainport Eindhoven quadruple-helix model is still in its infancy, and needs to be explored further within the Brainport Next Generation policy (Brainport Development, 2015). It would be interesting to extend our research into how to incorporate this fourth dimension within the existing system; and to connect this to other research on multiple- or quadruple-helix development, open innovation and living labs (Chesbrough, 2017). Earlier work of Cohen, Almirall, and Chesbrough (2016), about the city as a lab, introduces the increasing role of society as a driver for open innovation and entrepreneurship. These drivers can also be interpreted as interventions needed for continuous change and innovation within the ecosystem. However, this research also has limitations. During this study interviewees retired or changed jobs possibly affecting the stability of the ecosystem. Over time personal perspectives and changes in economic, political, social and environmental aspects will influence the core of the ecosystem requiring new

social ties. Co-creating a stable ecosystems is always 'work in progress' and this study reflects a certain moment in time.

Despite the limitation this case study provides an rich exploration of the history and successes of the Brainport Eindhoven innovation ecosystem. On the one hand, we can draw a parallel with the perception of an ecosystem as 'one big organization', with strategic, tactical, and operational levels. This is governed by the board members, placed in the Brainport Foundation and Brainport Development as the operating company, making strategic plans which are then carried out at the tactical and operational levels. On the other hand, we can perceive the Brainport Eindhoven ecosystem as a complex, multi-actor system; continuously transforming through both external and internal developments and crises. Constantly changing environments, operating on a global, national and regional scale, generate situations of high uncertainty (Kidd, 2008). According to Ivanova and Leydesdorff (2015), the dynamics within an innovative ecosystem, and its overall performance, strongly relate to the complexity of the ecosystem itself. The non-linearity of different activities within the ecosystem, as expressed through the actions of different stakeholders at different moments in time, clearly shows that managing the Brainport Eindhoven ecosystem cannot be based entirely on traditional thinking derived from the industrial era. We would therefore like to explore other perspectives on innovation ecosystems; viewing each of these as a Complex Adaptive System (CAS), requiring different approaches towards change and intervention. The work of Stacey was rooted in a view of organizations as a CAS. Later this perspective changed towards organizing as a process rather than seeing it as a system. This view is known as the "complex responsive process of relating" (Stacey, 2001) or the complex responsive process of communicative interaction in the living present. Actually that is what happens in the Brainport ecosystem and its development over the years. All actors are taking part in a complex social process of everyday human interactions (Rodgers, 2021). Applying the concept of dynamic capabilities (Teece et al., 1997) to innovation ecosystems also seems to be an interesting area of research. These aspects are also known in the fields of complexity and chaos. It would therefore be interesting to combine research about how to incorporate this fourth dimension in a quadruple-helix setting, drawing on the works from Stacey (2001) and Chesbrough (2017) about open innovation and Cohen et al. (2016) about the city as a lab. Our recommendation, at this point, is to combine research about the transfer to a 'quadruple-helix' ecosystem with research deriving from a complexity perspective on regional ecosystems.

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7 References

Albats, E. (2018). *Facilitating University-Industry Collaboration with a Multi-Level Stakeholder Perspective.* (Doctoral Dissertation). University of Technology, Lappeenranta

Arranz, N., & Fdez. de Arroyabe, J. C. (2007). Governance structures in R&D networks: An analysis in the European context. *Technological Forecasting and Social Change, 74*(5), 645-662. doi:https://doi.org/10.1016/j.techfore.2006.05.009

Bevir, M. (2012). *Governance: A very short introduction*: OUP Oxford.

Bjerregaard, T. (2010). Industry and academia in convergence: Micro-institutional dimensions of R&D collaboration. *Technovation, 30*(2), 100-108. doi:https://doi.org/10.1016/j.technovation.2009.11.002

Marcel Bogers, Ann-Kristin Zobel, Allan Afuah, Esteve Almirall, Sabine Brunswicker, Linus Dahlander, Lars Frederiksen, Annabelle Gawer, Marc Gruber, Stefan Haefliger, John Hagedoorn, Dennis Hilgers, Keld Laursen, Mats G. Magnusson, Ann Majchrzak, Ian P. McCarthy, Kathrin M. Moeslein, Satish Nambisan, Frank T. Piller, Agnieszka Radziwon, Cristina Rossi-Lamastra, Jonathan Sims & Anne L. J. Ter Wal (2017) The open innovation research landscape: established perspectives and emerging themes across different levels of analysis, Industry and Innovation, 24:1, 8-40, DOI: 10.1080/13662716.2016.1240068

Brainport Development. (2018). Brainport monitor 2016. Brainport blijvend succes. Retrieved from https://www.brainport.nl/over-brainport/brainport-monitor/archief/brainport-monitor-2016

Brainport Development. (2015). Brainport Next Generation vernieuwde strategie.

Brainport Development. (2018). Brainport Eindhoven maakt het samen. Retrieved from https://brainporteindhoven.com/fileadmin/user_upload/Brainport_Eindhoven/Brainport-Monitor-samenvatting-2018_1_.pdf

Brainport Development. (2019). Regio Deal Brainport Eindhoven. Retrieved from https://www.brainport.nl/over-brainport/actieagenda/regio-deal-brainport-eindhoven

Brainport Development. (2018). Rijksoverheid, & Provincie Noord-Brabant. Brainport Nationale Actieagenda

Bronneberg, M. (2018). *Literatuursynthese netwerk governance*. Literatuursynthese. Open Universiteit. Eindhoven.

Bronneberg, M. (2019). *Casestudy Brainport Eindhoven 'De invloed van stabiliteit op het vermogen van netwerken om te innoveren en te veranderen'.* (Master of Science Casestudy). Open University, Eindhoven.

Chesbrough, H. (2017). The Future of Open Innovation. *Research Technology Management, 60*(6), 29-35. doi:10.1080/08956308.2017.1373048

Clarysse, B., Wright, M., Bruneel, J., & Mahajan, A. (2014). Creating value in ecosystems: Crossing the chasm between knowledge and business ecosystems. *Research Policy, 43*(7), 1164-1176. doi:https://doi.org/10.1016/j.respol.2014.04.014

Cloutier, C., & Ravasi, D. (2021). Using tables to enhance trustworthiness in qualitative research. *Strategic Organization, 19*(1), 113-133.

Cohen, B., Almirall, E., & Chesbrough, H. (2016). The City as a Lab: Open innovation meets the collaborative economy. *California Management Review, 59*(1), 5-13. doi:10.1177/0008125616683951

Cornell, U., INSEAD, & WIPO. (2018). *Global Innovation Index 2018: Energizing the World with Innovation* (11 ed.). Ithaca; Fontainebleau; Geneva: Cornell University; INSEAD; WIPO.

Cristofoli, D., & Markovic, J. (2016). How to make public networks really work: a qualitative comparative analysis. *Public Administration, 94*(1), 89-110. doi:doi:10.1111/padm.12192

Crossan, M. M., & Apaydin, M. (2010). A Multi-Dimensional Framework of Organizational Innovation: A Systematic Review of the Literature. *Journal of Management Studies, 47*(6), 1154-1191. doi:https://doi.org/10.1111/j.1467-6486.2009.00880.x

D'Andreta, D., Marabelli, M., Newell, S., Scarbrough, H., & Swan, J. (2016). Dominant Cognitive Frames and the Innovative Power of Social Networks. *Organization Studies, 37*(3), 293-321. doi:10.1177/0170840615613374

Dahler-Larsen, P. (2005). Evaluation and Public Management. In E. Ferlie, L. E. Lynn Jr., & C. Politt (Eds.), *The Oxford Handbook of Public Management* (pp. 615-639). New York: Oxford University Press.

De Maeijer, E. D. R. (2020). *Open Innovation Dynamics – Languaging in industry-academia collaborations.* (Doctoral Dissertation). Technische Universiteit Eindhoven / Universiteit Antwerpen,

Dinwoodie, D. L., Criswell, C., Tallman, R., Wilburn, P., Petrie, N., Quinn, L., & McEvoy, L. (2014). *Transformational change: An ecosystem approach*. Retrieved from Greensboro, NC: https://doi.org/10.35613/ccl.2014.1020

Donald, M. (2019). *Leading and Managing Change in the Age of Disruption and Artificial Intelligence*. Bingley, United Kingdom: Emerald Publishing Limited.

Enroth, H. (2011). The SAGE Handbook of Governance. In. London: SAGE Publications Ltd.

Eoyang, G. H. (2011). Complexity and the Dynamics of Organizational Change. In P. M. Allen, S; McKelvey, B (Ed.), *The SAGE Handbook of Complexity and Management*. USA: UCLA.

Etzkowitz, H., & Klofsten, M. (2005). The innovating region: toward a theory of knowledge-based regional development. *R&D Management, 35*(3), 243-255. doi:10.1111/j.1467-9310.2005.00387.x

Ferlie, E., Fitzgerald, L., Wood, M., & Hawkins, C. (2005). The Nonspread of Innovations: The Mediating Role of Professionals. *The Academy of Management Journal, 48*(1), 117-134. doi:10.2307/20159644

Garud, R., & Karnoe, P. (2001). *Path Dependence and Creation*. Mahwah: Lawrence Erlbaum Associates, Inc., Publishers.

Geertsen, C. H. E., & Post, G. J. J. (2016). Collective ideation within the context of science and technology parks and regional economic clusters. *Studia Regionalia, 46*, 7-26.

Goes, J. B., & Park, S. H. (1997). Interorganizational Links and Innovation: The Case of Hospital Services. *The Academy of Management Journal, 40*(3), 673-696. doi:10.2307/257058

Gouvea, R., Kassicieh, S., & Montoya, M. J. R. (2013). Using the quadruple helix to design strategies for the green economy. *Technological Forecasting and Social Change, 80*(2), 221-230. doi:https://doi.org/10.1016/j.techfore.2012.05.003

Granstrand, O., & Holgersson, M. (2020). Innovation ecosystems: A conceptual review and a new definition. *Technovation, 90-91*(February-March), 102098. doi:10.1016/j.technovation.2019.102098

Gulati, R. (1995). Does Familiarity Breed Trust? The Implications of Repeated Ties for Contractual Choice in Alliances. *The Academy of Management Journal, 38*(1), 85-112. doi:10.2307/256729

Gulati, R. (1998). Alliances and networks. *Strategic Management Journal, 19*(4), 293-317. doi:https://doi.org/10.1002/(SICI)1097-0266(199804)19:4<293::AID-SMJ982>3.0.CO;2-M

Horizon. (2005). *De Horizon oogst*. Retrieved from Eindhoven:

Horsten, H. (2016). *The city that creates the future*. Eindhoven: Lecturis.

ICF. (2015). Eindhoven. Retrieved from https://www.intelligentcommunity.org/eindhoven

Ivanova, I. A., & Leydesdorff, L. (2015). Knowledge-generating efficiency in innovation systems: The acceleration of technological paradigm changes with increasing complexity. *Technological Forecasting and Social Change, 96*, 254-265. doi:https://doi.org/10.1016/j.techfore.2015.04.001

Kash, D. E., & Rycroft, R. W. (2003). To mnage complex innovation, ask the right questions. *Research Technology Management, 46*(5), 29-33. doi:10.1080/08956308.2003.11671585

Kidd, P. T. (2008). Agile Holonic Network Organizations. In D. P. Goran & C.-C. Maria Manuela (Eds.), *Encyclopedia of Networked and Virtual Organizations* (pp. 35-42). Hershey, PA, USA: IGI Global.

Kirkels, Y., & Duysters, G. (2010). Brokerage in SME networks. *Research Policy, 39*(3), 375-385. doi:https://doi.org/10.1016/j.respol.2010.01.005

Lintsen, H. W., & Thoben, P. (2009). *Inleiding : de canon van Eindhoven*. Eindhoven: Heinen.

Lönngren, J., & van Poeck, K. (2021). Wicked problems: a mapping review of the literature. *International journal of sustainable development and world ecology, 28*(6), 481-502. doi:10.1080/13504509.2020.1859415

Mahdad, M. (2016). *The Micro-dynamics of University-Industry Collaboration: The case of Telecom Italia Joint Open Labs.* (Doctor of Philosophy). Scuola Superiore Sant'Anna A.Y. ,

Mantere, S., & Ketokivi, M. (2013). Reasoning in organization science. *Academy of management review, 38*(1), 70-89.

Milward, H. B., & Provan, K. G. (2006). *A Manager's Guide to Choosing and Using Collaborative Networks*. Retrieved from Arizona:

Moore, J. F. (1993). Predators and prey: A new ecology of competition. *Harvard Business Review, 71*, 75-86.

OECD. (1999). *Managing National Innovation Systems*. Paris: OECD Publishing.

Oh, D.-S., Phillips, F., Park, S., & Lee, E. (2016). Innovation ecosystems: A critical examination. *Technovation, 54*, 1-6. doi:https://doi.org/10.1016/j.technovation.2016.02.004

Osborne, S. P., & Brown, K. (2005). *Managing Change and Innovation in Public Service Organizations*. 2 Park Square, Milton Park, Ahingdon, Oxon OX14 4RN: Routledge.

Pieterse, J. H., Caniels, M. C. J., & Homan, T. (2012). Professional discourses and resistance to change. . *Journal of Organizational Change Management, 25*, 798-818. Retrieved from https://doi.org/10.1108/09534811211280573

Pique, J. M., Berbegal-Mirabent, J., & Etzkowitz, H. (2018). Triple Helix and the evolution of ecosystems of innovation: the case of Silicon Valley. *Triple Helix, 5*(1), 11. doi:10.1186/s40604-018-0060-x

Powell, W. W. (1987). Hybrid Organizational Arrangements: New Form or Transitional Development? *California Management Review, 30*(1), 67-87. doi:10.2307/41165267

Provan, K. G., Fish, A., & Sydow, J. (2007). Interorganizational Networks at the Network Level: A Review of the Empirical Literature on Whole Networks. *Journal of Management, 33*(3), 479-516. doi:10.1177/0149206307302554

Provan, K. G., & Kenis, P. (2007). Modes of Network Governance: Structure, Management, and Effectiveness. *Journal of Public Administration Research and Theory*.

Provan, K. G., & Lemaire, R. H. (2012). Core Concepts and Key Ideas for Understanding Public Sector Organizational Networks: Using Research to Inform Scholarship and Practice. *Public Administration Review, 72*(5), 638-648. doi:doi:10.1111/j.1540-6210.2012.02595.x

Provan, K. G., & Milward, H. B. (1995). A Preliminary Theory of Interorganizational Network Effectiveness: A Comparative Study of Four Community Mental Health Systems. *Administrative Science Quarterly, 40*(1), 1-33. doi:10.2307/2393698

Ramezani, J., & Camarinha-Matos, L. M. (2020). Approaches for resilience and antifragility in collaborative business ecosystems. *Technological Forecasting and Social Change, 151*, 119846. doi:https://doi.org/10.1016/j.techfore.2019.119846

Ring, P. S., & van de Ven, A. H. (1994). Developmental Processes of Cooperative Interorganizational Relationships. *The Academy of Management Review, 19*(1), 90-118. doi:10.2307/258836

Ritala, P., & Almpanopoulou, A. (2017). In defense of 'eco' in innovation ecosystem. *Technovation, 60-61*, 39-42. doi:https://doi.org/10.1016/j.technovation.2017.01.004

Rodgers, C. (2021). *The Wiggly World of Organization: Muddling Through with Purpose, Courage and Skill*: Routledge.

Russell, M. G., & Smorodinskaya, N. V. (2018). Leveraging complexity for ecosystemic innovation. *Technological Forecasting and Social Change, 136*, 114-131. doi:https://doi.org/10.1016/j.techfore.2017.11.024

Rycroft, R. W. (2007). Does cooperation absorb complexity? Innovation networks and the speed and spread of complex technological innovation. *Technological Forecasting and Social Change, 74*(5), 565-578. doi:https://doi.org/10.1016/j.techfore.2006.10.005

Shipilov, A., & Gawer, A. (2020). Integrating Research on Interorganizational Networks and Ecosystems. *Academy of Management Annals, 14*(1), 92-121. doi:10.5465/annals.2018.0121

Siciliano, M. D., & Whetsell, T. A. (2021). Strategies of Network Intervention: A Pragmatic Approach to Policy Implementation and Public Problem Resolution through Network Science. *arXiv preprint arXiv:2109.08197*.

Stacey, R. D. (1995). The Science of Complexity: An Alternative Perspective for Strategic Change Processes. *Strategic Management Journal, 16*, 477-495.

Stacey, R. D. (2001). *Complex Responsive Processes in Organizations: Learning and Knowledge Creation*. London: Routledge.

Stam, E. (2015). Entrepreneurial Ecosystems and Regional Policy: A Sympathetic Critique. *European Planning Studies, 23*(9), 1759-1769. doi:10.1080/09654313.2015.1061484

Taleb, N. N. (2012). *Antifragile: Things that gain from disorder* (Vol. 3): Random House Incorporated.

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic management journal, 18*(7), 509-533.

Tidd, J., & Bessant, J. (2018). *Managing Innovation: integrating technological, market and organizational change* (6th ed.). Hoboken.

Torfing, J. (2012). Governance Networks. In D. L.-F. (Ed.) (Ed.), *The Oxford Handbook of Governance* (pp. 99-112). New York: Oxford University Press Inc.

Turrini, A., Cristofoli, D., Frosini, F., & Nasi, G. (2010). Networking literature about determinants of network effectiveness. *Public Administration, 88*(2), 528-550. doi:doi:10.1111/j.1467-9299.2009.01791.x

Valente, T. W. (2012). Network Interventions. *Science (American Association for the Advancement of Science), 337*(6090), 49-53. doi:10.1126/science.1217330

Van Aken, J. E., Hop, L., & Post, G. J. J. (1998). *The virtual organization : a special mode of strong interorganizational cooperation*. Chichester: Wiley.

Van de Ven, A., Polley, A., Garud, S., & Venkataraman, S. (2007). *The innovation journey*. New York.

Vangen, S., & Huxham, C. (2003). Nurturing Collaborative Relations:Building Trust in Interorganizational Collaboration. *The Journal of Applied Behavioral Science, 39*(1), 5-31. doi:10.1177/0021886303039001001

Vermeer, J. (2020, 31-03-2020). Brainport pleads for financial support of startups. Retrieved from https://bits-chips.nl/artikel/brainport-pleads-for-financial-support-of-startups/

Yin, R. K. (2014). *Case Study Research* (5 ed.): SAGE Publications.

Zahra, S. A., & Nambisan, S. (2011). Entrepreneurship in global innovation ecosystems. *AMS Review, 1*(1), 4. doi:10.1007/s13162-011-0004-3

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