# Chapter 6
# Quadruple Helix Relational Approach to Recycling Fishing Nets: Cluster Development in the Norwegian West Coast Region


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**Abstract** The study presented in this chapter takes the quadruple helix relational perspective to develop a regional innovation cluster for fishing nets recycling and upcycling. A multi-method approach is proposed—triangulating cluster development approaches with the quadruple helix model of innovation and organisational network analysis—to explore clustering abilities by network structures that promote linkages for well-organised circular value chains, regional innovation processes, brokerage of innovative ideas and other cluster-related structures, and relational patterns.

**Keywords** Cluster · Quadruple helix · Organisational network · Fishing nets · Circular value chain

## 6.1 Introduction

Pollution from fishing vessels and installations is recognised as one of the most serious environmental threats globally, with 46% of the Great Pacific Garbage Patch made up of fishing nets (Lebreton et al. 2018). The International Maritime Organisation IMO's Marine Environment Protection Committee (2021) has developed regulations and recently launched its strategy to reduce marine plastic litter (IMO 2021). However, many seaports are neither equipped with the necessary infrastructure nor technology, nor operational capabilities to receive, sort, store, and treat this type of waste (Deshpande and Haskins 2021). Businesses engaged in recycling-upcycling

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activities are also relatively few in number, as compared to the amount of recyclable waste, and most of them are in their early product and technology development phase, with rather immature value chains. To facilitate the development of specialised knowledge and technological capabilities needed, to solve the marine plastic litter problem, new stakeholder constellations and coordination between original equipment manufacturers, operators, and innovators are needed, as well as coordination with governmental units (Kalverkamp 2018).

Circular supply chains to transform discarded fishing nets into new business opportunities (i.e. new marketable products) are expected to lead to solutions that increase the circulation of raw materials and that hinder the waste from entering the ocean. Innovation and entrepreneurship are recognised as driving forces for circular supply chains and corresponding business models (Charter 2018; Iglesias-Sánchez et al. 2016), with collaboration with external actors and trust-based engagement as facilitators of the development of new capabilities to innovate through such models (Vildåsen 2018); e.g. collaboration between industry and academia helps to develop new internal competencies and sharing of early research results, and experience accelerates the development process and the adoption of circular business models. Collaboration with governmental units helps to spread circular economy research by providing financial support that facilitates industry-academia collaboration. These relational benefits are leading to the triple helix model of innovation (Etzkowitz and Leydesdorff 1995), as an approach to better understanding interactions between businesses, universities, and governmental units that may facilitate new business opportunities from fishing nets recycling. The sociocultural dimension of marine plastic litter suggests that innovations in this direction are also to be anchored in the needs and feedback from civil society (e.g. end-users, consumers, non-governmental organisations, and volunteers for beach cleaning). The quadruple helix, as an enhancement of the triple helix to also include civil society (Carayannis and Campbell 2009; Höglund and Linton 2018), puts the relational aspect between the three initial helices into the larger sociocultural context (McAdam and Debackere 2018; Nordberg 2017).

Against this background, the chapter at hand discusses how *the quadruple helix as a network of relations* can be applied to facilitate the development of a regional cluster for new business opportunities from reuse and recycling of discarded fishing nets. The Norwegian West Coast region already has strong cultural traditions for trust-based and reciprocal networking and clustering for technology-driven innovation and entrepreneurship, in the marine and maritime businesses. Long shipbuilding traditions and cutting-edge technology, coupled with global operations, ensured access to the fastest-growing markets (e.g. aquaculture, cruise, exploration), with flexibility and responsiveness to market changes and societal challenges as important enablers of the competitive advantage for cluster members (Hansen et al. 2020; Vaagen et al. 2016), and for the region at whole. Established relational and innovation capabilities, as well as regional specificities, are hence a valuable source of learning for new cluster initiatives, such as the one at hand. Cultural factors play a critical role in innovation and entrepreneurship, as these are stable over time due to shared values, norms of behaviour, and beliefs that also define the identity of people and organisations in the region (Ranga and Garzik 2015).

The network view of quadruple helix relations led us to the investigation of organisational (social) network analysis as a potential theoretical approach and methodology to study the relational properties that facilitate knowledge transfer, learning, combined resources, innovative ideas, and cooperation in the emerging cluster. Network theory provides an answer to how individuals (humans or organisations) can combine to create well-functioning systems and societies and provides explanations for different social phenomena, from individual creativity to corporate profitability (Borgatti et al. 2009). For a review of the network analysis in social sciences, with basic assumptions, goals, and explanatory mechanisms, see Borgatti et al. (2009), and for a discussion of its application in cluster development programmes, we refer to Pietrobelli and Giuliani (2011).

The research foundation is, as such, developed by triangulating cluster development approaches with the quadruple helix and organisational network analysis. The literature leading to the research foundation is reviewed in Sect. 6.2. The methodological approach is given in Sect. 6.3, with preliminary results in Sect. 6.4, and conclusion with future research directions in Sect. 6.5.

## 6.2 Theoretical Background

### *6.2.1 Clusters*

Cluster policies aim to promote collective processes of growth and innovation in a regional area. These share at least three aspects that are also relevant for the discussion at hand (Pietrobelli and Giuliani 2011). First, they target a group of actors that are typically (but not necessarily) localised in a geographically bounded area. Second, clustering programmes are tailored to industry specificities and maturity, the stage of the cluster lifecycle, and regional characteristics. Third, cluster policies are grounded in one of two ideas, to search for higher innovation or to search for more efficiency in production; both of which are best achieved when firms collaborate and share resources. The latter suggests that a central principle of many cluster policies is the promotion of linkages and networks.

Efficient networks are recognised as social processes involving the interaction, cooperation, and alliance of different actors (Freeman 1991; Powell et al. 1996), with clear advantages to access resources, reduce information asymmetries, improve information quality, enable higher bargaining power, strengthen the lobbying power, enable firms to upgrade their capabilities, and generate innovative ideas. That said, conventional cluster programmes target general groups of actors and often stop at the level of identifying individuals in major categories in the cluster (Ketels 2013), e.g. suppliers of raw materials, designers, and clients. Key concepts like networking, connections, and linkages are often measured by aggregated indicators that only capture the connections between general categories but fail to account for the diversity of connections between individuals within each category. E.g. within the group

of fishing nets, suppliers may be individuals with leading roles in R&D activities for recycling, shaping the cluster future. Macro-level clustering approaches cost-effectively account for the presence of collaborative networks and are justifiable by practical motivations. However, aggregated network measures may hide more than they reveal (Pietrobelli and Giuliani 2011), a general property of average values.

Furthermore, conventional cluster policies focus on strengthening existing networks rather than creating new ones, building on established regional economic performance and evolution (Ketels 2013). This makes it challenging to study innovation and entrepreneurship, as the main drivers of innovation-driven economies like the Nordic countries (Bosma and Levie 2010; Porter and Lopez-Claros 2004). Efficiency-driven economies, with a primary focus on growth and economic development, also increasingly turn to strengthen the private sector and develop public incentives for the development of the economy. Thus, entrepreneurship is important for the development of a country (Martínez-Fierro et al. 2016), and the entrepreneur is the best changing agent (Acs and Amorós 2008; Bosma and Levie 2010). As such, clustering approaches for the scope at hand must also capture the innovation and entrepreneurship capabilities.

### *6.2.2 Quadruple Helix*

Innovation, entrepreneurship, and economic growth are directly related. Countries that achieve an increase in innovation and entrepreneurship also achieve higher rates of economic growth (Galvão et al. 2017). Galvão et al. (2017) apply the four dimensions of the quadruple helix model to propose a theoretical framework for entrepreneurship as a tool for economic development. The quadruple helix, extended from the triple helix (Etzkowitz and Leydesdorff 1995) to bridge the gap between innovation and civil society, emphasises the societal responsibility of universities besides their roles in education and research, and the need for tight interactions with industries producing commercial goods, governments regulating markets and providing financing, and the civil society (e.g. end-users, consumers, media, other). The quadruple helix claims that under the triple helix, the emerging technologies and innovations enabled by these do not always match the demands and needs of society, thus limiting their potential impact (Volpe et al. 2016). The fourth helix is defined as:

> A collective entity formed by individual users living on a territory and interacting with university, industry, and government as customers, citizens, or members of a community in order to contribute to build new innovation paths which are able to promote the socio-economic growth of the territory. Civil society demands that innovations are made according to its needs, releases feedback on products and services (and on their innovation value), and provides its own contribution in terms of knowledge, inventiveness, and creativity. Civil society is constantly interacting with the other three helices as a result of enabling technologies for information and communication which make social inclusion possible in real time and at low cost (Volpe et al. 2016).

In summary, the quadruple helix model is seen as a network of relations where public and private organisations interact in a value-creating process. It is also the approach the European Union intends to take for the development of a competitive knowledge-based society (Volpe et al. 2016). As interactions increase within this framework, each component evolves and adopts characteristics of the other institution, leading to hybrid organisations that facilitate entrepreneurship and innovation (Champenois and Etzkowitz 2018). Hybrid organisations, such as science parks, incubators, and catapult centres, act as a catalyst between actors in the quadruple helix network. One of the practical instruments of the triple and quadruple helix models is innovation clusters, with Silicon Valley as the most known cluster for new technologies and industries (English-Lueck 2017; Etzkowitz 2012).

To measure what the four helices represent in terms of economic development, multiple variables, and factors of influence are proposed (Carayannis and Campbell 2009; Etzkowitz and Leydesdorff 1995; Galvão et al. 2017). The transfer of specialists between university and industry measures knowledge transfer. Interactions between governmental units and universities depend on the government's policy on higher education and the strategic demands. The government, as the main source of funding, has a high influence on universities. Government and industry relations depend on the government's strategy towards specific markets. The key roles of the government in its interaction with industry are to regulate specific markets and to establish intellectual property law and its enforcement. Further, Galvão et al. (2017) show that innovation-driven economies exhibit greater relevance in the industry and government dimensions, with variables of high influence, 'R&D transfer' and 'financing for entrepreneurs'. The authors propose that a strong link between government and industry suggests strong R&D transfer from universities according to the needs of industry and government, which is important for innovation.

### *6.2.3 Critiques of the Triple and Quadruple Helix Models and Call for New Perspectives*

The importance of collaboration in a quadruple helix puts the relationship aspect between the four helices in focus. This resulted in quadruple helix research from different perspectives, from supply chain to regional innovation management. However, studies take a macro-level perspective, fail to account for the micro-level relational specificities and value-creating activities through these relations, and consequently, also fail to assess the economic value generated by these relations (Hasche et al. 2020; Höglund and Linton 2018; McAdam and Debackere 2018; Miller et al. 2018). Examples of questions that are relevant in innovation management, but difficult to address on a macro-level, are as follows: 'who do we need to involve to generate innovative ideas, and who will help to implement these? Who are peripheral actors that represent untapped expertise and how to proactively involve them so that new connections for generating creative ideas can emerge? Who are the

information brokers'? To answer these questions, research into individual relational perspective and the combined resources and activities such relations enable is needed (McAdam and Debackere 2018). Cunningham et al. (2018) emphasise the need to better understand the micro-aspects of relationships, to enhance knowledge of the dynamic relationships that arise between individual stakeholders, synergies between relations, collaborations, coordinated environments, and value-creating activities.

The micro-level relational perspective of innovation is supported by social science research, highlighting that innovation is generated by creative 'individuals', embedded within a network of interdependent ties (Simonton 2013) and that creativity lays at the nexus of the individual and the larger sociocultural context (Cattani and Ferriani 2008; Csikszentmihalyi 1997, 2014). Organisational network analysis from social sciences is a theoretical and methodological approach that proves valuable to uncover the micro-level relational aspects of networks. It is a research perspective based on the assumption that relationships amongst interacting actors (organisation or people level) are important in explaining their nature, behaviour, and outputs. The ONA facilitates quantitative or qualitative analysis by describing features of a network either through numerical or visual representations. ONA has been proposed as appropriate for cluster development (Pietrobelli and Giuliani 2011; Giuliani 2011), but practical applications are few. Examples are found in Breznik (2016) and Woods et al. (2019). The latter points to the position of a firm within the network of a low-technology cluster as important for new product development innovation. Further, firms occupying central network positions by their connection to many other members of the cluster, typically demonstrate greater innovation capabilities. Size, absorptive capacity, and managerial orientation are factors highlighted to influence a firm's network position in a cluster.

## 6.3 Methodology and Context of Analysis

### *6.3.1 Methodology*

Organisational network analysis (ONA) is chosen as the methodology to explore regional cluster development abilities, to better understand where and what collaborative efforts are present, and what connections are needed to be strengthened or enabled, to stimulate cluster development. The selection of ONA suggests a move towards systems of relations of intertwined actors. The network of connections that enable quick transfer of innovative ideas, information and resources, and norms of behaviour within these networks (i.e. trust, obligations, and risk behaviour) provides the motivation to combine resources and generate solutions to emerging problems. Trust is a relational dimension of the social capital and is connected to the motivation to share and combine information and knowledge but also to the extent of resource exchange and product innovation (Tsai and Ghoshal 1998). Recall from Sect. 6.1

that capabilities needed to innovate through circular models is likely to arise in trust-based collaboration networks with external actors (Vildåsen 2018). Further, research shows that information exchange in a network is not random, but people and organisations seek advice from those they trust, although more qualified ones may be available (Casciaro and Lobo 2005). Therefore, the way actors are connected within a network structure says much about available resources and innovation potential (Burt 2004; Marsden 1990).

The ONA approach generates an understanding of the advantages and disadvantages of different network positions and structures in the cluster. These may differ from context to context. One structure of relevance for cluster development is *the promotion of linkages for regional innovation processes*, e.g. linkages between government and industry may strengthen R&D transfer from universities according to the needs of the industry and government (Galvão et al. 2017). The desired output for regional innovation processes may be *local cliques* connected by a few ties, to facilitate the sharing of creative ideas and high-quality knowledge, thus generating opportunities for innovation (Pietrobelli and Giuliani 2011). A second output may be 'core-periphery' structures with a core of densely connected actors and a periphery of few connections brokering new ideas from external actors (Cattani and Ferriani 2008). Too many connections can also be detrimental for innovation, and cluster development initiatives may focus on promoting connections only amongst partners that have something valuable to share. Avoiding redundant ties is, hence, important, and building connections with external actors (*small worlds*) and promoting diversity (*structural holes*, *brokerage*) are desirable to generate new ideas and creative outputs. Technological gatekeepers, as actors who acquire knowledge from outside cluster boundaries and contribute to technology diffusion within the cluster, are important for the growth of industrial and technology-driven innovation clusters (Giuliani 2011).

A second network structure with advantages to cluster development is *the promotion of well-organised regional value chains.* The desired network output may be a *hierarchical structure*, coordinated by one or few leading firms, orchestrating the local value chain and connecting it to markets and other stakeholders. Cluster development initiatives may, therefore, focus on selected connections and on increasing the centrality of some of the leading firms, whilst leaving others (for example, suppliers that only need to connect to their key customers) in less central positions.

### *6.3.2 Context of Analysis*

Motivated by the dominant cluster development practices in the Norwegian West Coast region—i.e. facilitating well-functioning manufacturing value chains in the maritime and marine businesses—the clustering initiative at hand takes the *generic circular value chain* starting approach for fishing net recycling and upcycling (see Fig. 6.1 for illustration). The current value chain demonstrates a well-functioning forward stream of fishing rope manufacturing and operations systems, and a less mature reverse stream with missing connections, but also with a few leading actors

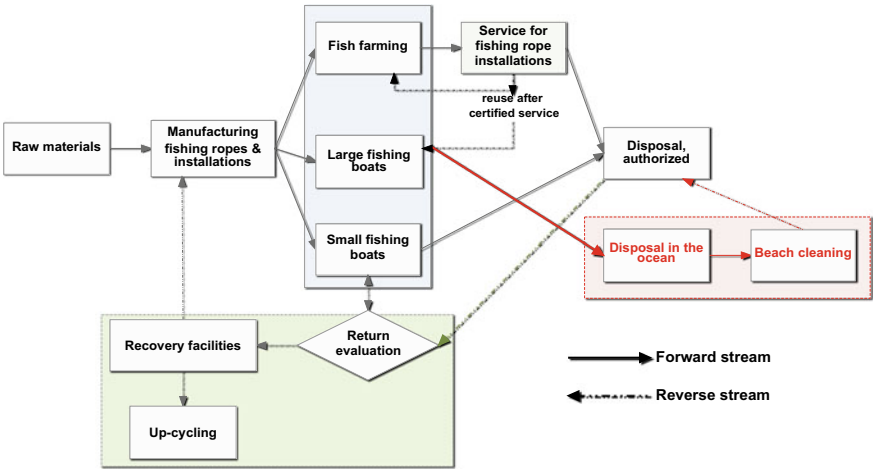


**Fig. 6.1** Generic circular supply chain for fishing nets recycling and upcycling

potentially shaping the future of the reverse chain. Disposal of marine debris is regulated by IMO in order to facilitate a reverse stream from fishing boats and from service companies of fishing rope installations. However, many seaports are lacking facilities and competencies to handle disposed fishing nets, and a large share of fishing gear is discarded, lost, or abandoned in the marine environment (also known as 'ghost fishing'). These deficiencies necessitate new collaboration links, e.g. between authorities and aquaculture businesses to develop infrastructure for waste collection, sorting, and registration. Other connections of relevance are between volunteers cleaning up beaches and governmental units, in order to incentivise, formalise, and compensate volunteer work. Furthermore, collaboration paths between new businesses and governmental bodies are needed to enable flexible financing for entrepreneurs to develop new regulations and quality standards of recycled-upcycled products, to avoid inferior new products and unfair pricing, and to boost competition. Finally, the collaboration between academia and industry is also needed (e.g. by research projects and entrepreneurial education) for new product development from recycled fishing nets and for circular business models to be adopted by SMEs.

To enable these relations beyond supply chain collaborations to develop and deliver a product or service to a customer, the generic supply chain network is extended following the quadruple helix, to also include stakeholders from *government*, *academia*, the *civil society*, as well as *hybrid institutions* (such as science parks and incubators) that connect different actors and act as a catalyst in the network. The list of actors within the four helices makes up the early-phase cluster network, which stands as a basis for explorative ONA studies.

## 6.4 ONA Research Design, Data Collection, and Preliminary Results

An inter-organisational ONA research design is applied with relational data collected to enable mapping and visualisation of collaboration networks in the quadruple helix, as defined in Sect. 6.3. Relational data are collected by asking actors about their contact with other actors in the network; each respondent is asked to select individual organisations from a list. This differs from other approaches, as it asks about relationships between identifiable actors, and not between general categories or groups of actors. The respondents then categorised each connection with respect to the frequency of contact during the last year, measured by Likert scale. Organisational network visualisation and analysis tools used are UCINET NetDraw 2.178. The network underlying the data collection counts 69 organisational units. The aim is to explore current clustering abilities and to use the results to stimulate further cluster development and policy design activities.

### *6.4.1 Preliminary Results*

Based on the questionnaire responses, the networks were constructed to visualise the relations in the preliminary cluster, the individuals' centrality in the network (defined by the number of direct ties one actor has with others in the network) with advantages for easy access to information, knowledge and resources, distance between nodes, and other important network measures. The network graphs are defined by nodes and the relations between the nodes. To rigorously treat anonymity, the major ethical issue embedded in network research design, outputs are presented by conventional versions that illustrate specific concepts, and participants (nodes) are presented by numbers and the helix vector they belong to.

The full network with frequent connections between individuals is visualised in Fig. 6.2. University is presented by blue circular nodes (7 actors), industry by red rectangular nodes (36 units), government by black triangle nodes (12 actors), and the civil society by green diamond nodes (13 actors). It is a dense network with few actors occupying central positions in the network (indicated by the node size). By zooming into the subnetworks of the four helices and into the ego-networks of central actors, structures of relevance for cluster development are detected. Two examples are given below, to illustrate central concepts for the promotion of value chains and innovation linkages.

**Example 1** Looking at the industry subnetwork in Fig. 6.3, a *small world* with nodes (10, 13, 16, 22, 35) is detected (as highlighted). There, node 10 is a waste management company, node 13 is a recycling-upcycling manufacturer of discarded fishing nets into new raw materials, node 16 is a leading regional manufacturer and recycler of plastic products, node 22 is a fishery association, and node 35 provides consultancy for ocean plastic waste cleaning, recycling, and innovation activities.

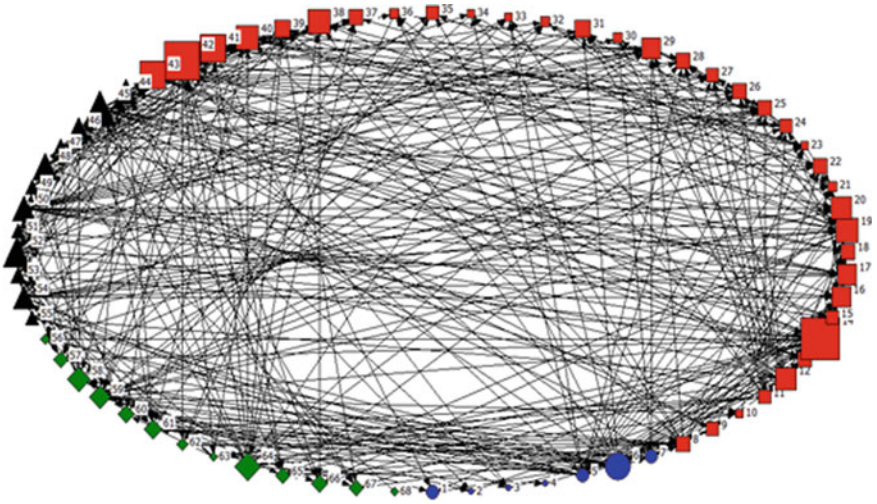

**Fig. 6.2** Full cluster network

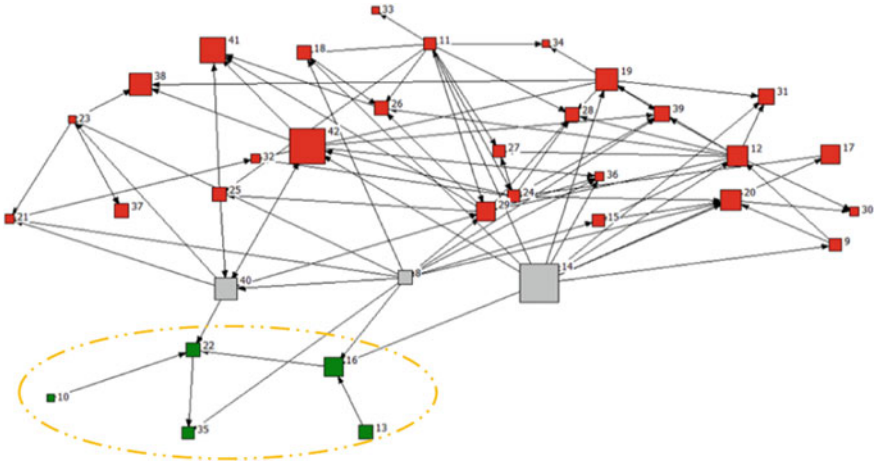

**Fig. 6.3** Industry subnetwork. The 'small world' of nodes 10, 13, 16, 22, 35 (highlighted) connects to the network by a) value chain relations (nodes 8 and 14) and b) innovation processes (node 40)

This 'small world' connects to the industry subnetwork by two distinct structures: (i) *value chain relations* driven by the core activities of node 8, a leading recycling company of fishing rope nets, and node 14, a leading producer of fishing nets and equipment; and (ii) *innovation processes* through node 40, which is a hybrid organisation with incubator role for innovation in the marine and maritime industries. Node 40 connects complementary businesses by facilitating the transfer of new knowledge and innovative ideas; hence, important for innovation in the cluster. The *small world*

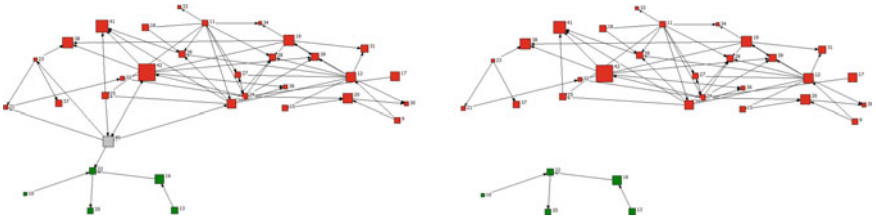

**Fig. 6.4** Industry subnetwork with and without node 40, which is an influencer for promoting linkages for regional innovation

nodes, the connector nodes, and the remaining of industry nodes, are differentiated by colour. Node size reflects actor centrality in the full cluster network.

In organisational network theory, a gap between two groups of actors with complementary resources and information is known as a *structural hole* (Burt 2004). When the two groups of actors are connected by a third actor, the gap is filled, creating important advantages in terms of information and knowledge brokerage. According to Burt (2004), competitive advantage and early access to key information is a matter of access to structural holes. The concept is illustrated by Fig. 6.4, where the supply chain connector nodes from Fig. 6.3 (8 and 14) are removed. The connector node 40, an incubator to promote innovation, is illustrated on the first network and removed on the second one, to illustrate the structural hole. The results suggest node **40** to be an influencer, *important for the promotion of linkages for regional innovation processes.*

**Example 2** The *promotion of well-organised regional value chains* is highlighted as a second network structure with advantages to cluster development. These relations are studied by the ego-network of leading industrials, such as node **14**, a leading producer of fishing rope installations. Its ego-network is visualised by the circle layout in Fig. 6.5, where 'own' supply chain members are presented by the rectangular industry nodes, connection to governmental units by links to triangles, to university and research institutions by links to circles, and to the civil society by links to the diamond nodes. The right side of Fig. 6.5 illustrates the supply chain subnetwork, with connections driven by economic transactions. Node size indicates actor centrality in the full network in Fig. 6.2, suggesting node **14** to be a *central player coordinating its value chain and connecting it to other actors in the cluster*. We also see that node 14 connects to multiple university nodes, highlighting R&D collaboration and knowledge transfer. University relations do not directly and immediately affect supply chain activities, but these facilitate the transfer of knowledge and innovative ideas and are expected to affect the cluster network in the long run.

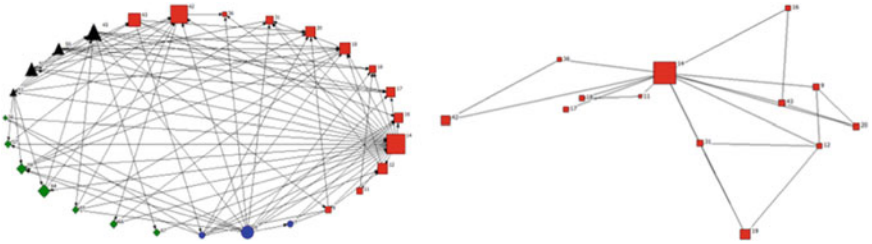

**Fig. 6.5** Ego-network of industry node 14, with all quadruple helix relations on the left side, and only industry nodes on the right side of the figure

## 6.5 Conclusion

The research presented is a regional cluster development initiative through the relational lenses of the quadruple helix model of innovation. The aim was to explore current clustering abilities and stimulate further research about cluster development to solve the marine plastic litter problem. The cluster is in its early development phase, with established actors for regular operations, but with few innovators taking initiator roles to develop upcycling value chains. Thus, the network as an early-phase cluster suffers from the deficiency imposed by insufficient reverse-chain relations. Future clustering activities will therefore need to zoom into the value-creating reverse and circular activities of actors with influential roles and also zoom into policy-oriented decision-making paths leading to sustainable circular solutions. This is needed to increase cluster maturity by further identifying and connecting actors of influence and to uncover network strengths and weaknesses where further clustering activities are needed.

As a final point, cluster evaluation by ONA provides intermediate outputs where the value of networks is determined by network size and strength and relational characteristics (such as trust and brokerage of innovative ideas). These studies are to be complemented with knowledge of the economic value the firms draw from these relations and an understanding of the economic and societal benefits of a particular policy. This is needed to legitimate further networking actions in a particular direction and to assess the learning on how to make future projects for fishing net recycling more effective, by understanding what factors or mechanisms are held responsible for a policy's success.

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