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NETWORK INSIGHTS FOR PARTNER SELECTION IN INTER-ORGANISATIONAL NEW PRODUCT DEVELOPMENT PROJECTS

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1. Introduction

Selecting partners for new product development (NPD) is an important yet under-supported task. This paper focuses on decision-making support for the NPD collaboration stages of partner exploration and search. We provide a conceptual framework for a network-based platform to identify potential research- and innovation partners. The framework integrates prior research on factors determining successful NPD collaborations and makes the factors actionable by connecting them to what is often publicly available data.

Four categories of success factors for collaborations are included in the framework: technological closeness, relational closeness, geographical closeness and a set of organisational variables. In order to identify a subset of new product development partners and aid the selection process, three characteristics of NPD projects are considered as mediators of those success factors: the desired degree of innovativeness of the NPD project, the initial technological maturity of the NPD project, and the combination of time and budget constraints. The proposed framework describes each of these factors, their mediators, and the interplay between them.

Using the conceptual framework as a guide, we also propose and illustrate with examples the network-based platform to explore NPD partners. The developed framework and platform are part of *Net-Sights*, an ongoing research project to develop open-source decision-support tools for network insights. The first version of this tool will soon be available as an online platform to support inter-organisational and collaborative sustainable production projects in Denmark.

1.1. Challenge

In order to respond to increasingly complex technical demands and fast paced competitive markets, organisations search for solutions outside their organisational boundaries, entering into different types of collaborative new product development (NPD) partnerships [Song, Ming, and Wang 2012]. In this context, early identification and selection of partners becomes strategically significant and can determine the result of an entire NPD project [Buonansegna 2014; Littler, Leverick, and Bruce 1995]. The strategic importance of partner exploration and search lies in the magnifying effect that path dependency has on early NPD process decisions. What is more, with partner selection being one of the earliest decisions taken in large NPD processes, a large number of subsequent decisions are affected. For example, it has been reported that selecting unsuitable partners often leads to project delays, knowledge gaps, higher costs, and in a worst case scenario, complete project failure [Buonansegna 2014; Emden, Calantone, and Droge 2006]. In NPD projects designing large engineering systems, the previous considerations become even more relevant. These projects typically require the inclusion of

many partners with often different sets of mutually complementary know-how; increasing the importance and impact of the partner selection process even further.

However, despite the importance and impact of NPD partner selection, this task is often under-supported [Emden et al. 2006]. Some of the challenges influencing this task include the large amount of partners that can be potentially considered and the difficult concurrent evaluation of all relevant variables. Key factors include technical needs, relational closeness, geographical closeness and a number of other organisational variables that are known to affect the chances of success in NPD collaborations [Büyüközkan et al. 2011; Li-Ying, Wang, and Salomo 2014; Parraguez and Maier 2012]. Furthermore, each NPD project has its own unique characteristics and needs, making generic advice insufficient and potentially counterproductive [Emden et al. 2006]. For instance, if we take the case of the cleantech industry in Denmark, we find in a relatively small geographical space more than 1.200 technologically diverse cleantech-related companies, more than 46 research institutions with cleantech-related activities, and a wealth of public and private organisations providing different types of services and support for NPD projects [Danish Ministry of Foreign Affairs 2014; Parraguez and Maier 2012]. In such circumstances, an organisation looking for an appropriate NPD project partner finds itself with a large set of options and criteria to consider, and at the same time, insufficient support, time, and budget to systemically and systematically analyse the options. In other words, the search cost for NPD partners appears higher than the perceived benefits of searching for partners if all known potential partners and selection criteria are to be considered [Li-Ying et al. 2014].

As a result, despite previous research examining success factors in inter-organisational collaborations and the growing amount of available industry data, it is common practice to select NPD partners following a process that is heavily affected by availability bias, driven by chance, gut feeling, and a narrow set of previous experiences [Emden et al. 2006]. Under these conditions, the process of NPD partner exploration and search is therefore likely to lead to sub-optimal partnership decisions and, as a consequence, negatively affect the end results of the NPD project.

1.2. Outline of the paper

The rest of this paper is structured as follows. Section two introduces previous research and tools with an emphasis on identifying success factors and relevant measures for inter-organisational NPD partner selection and shows current gaps in theory and practice. Section three develops our proposed network-based framework to explore and search for new product development partners. Section four provides an application example of the framework. Section five concludes with implications for theory and practice and an outlook for further research.

2. Previous research and tools

The study of inter-organisational partnerships or collaborations is a broad area, with research examples from a number of disciplines (for reviews see [Buonansegna 2014; Büyüközkan et al. 2011; Emden et al. 2006; Song et al. 2012]). To name just a few, there are organisational studies focused on inter-firm management issues, supply chain studies focused on input-output exchanges between firms, social network studies focused on inter-firm communications or relations, and inter-organisational collaborative new product development studies, focused on the collaborative relationship between two or more firms seeking to develop a new product or service. Furthermore, the study of inter-organisational partnerships or collaborations can also be analysed with a focus on different stages of the collaboration process [Fraser, Farrukh, and Gregory 2003]. Such stages range from early exploration and search of potential partners, up to managing the latest stages of collaboration processes, such as collaboration outputs and revision. The framework proposed here intersects inter-organisational collaborative new product development studies and studies focused on the stages of exploration and search of partners.

2.1. Success factors and measures for inter-organisational collaboration

The study of inter-organisational collaborative new product development focusing on the early stages of exploration and search of partners can more generally, be thought of as a problem with three types

of variables: A) a set of independent variables related to factors known to affect the success of inter-organisational collaborations, B) a set of dependent variables that measure the success of inter-organisational collaboration, and C) a set of mediators that modify the effect of the success factors associated with the specific characteristics of each NPD project. In what follows, we draw on previous research for theoretical and empirical results for each of these three types of variables.

A) Success factors for inter-organisational collaboration

Previous research provides evidence for a number of factors affecting the success of inter-organisational collaborations (for reviews see e.g. [Büyüközkan et al. 2011; Littler et al. 1995]). Narrowing down the analysis to factors that can be used as decision-making input during the stages of partner exploration and search, we have organised the factors into four categories: technological closeness, relational closeness, geographical closeness, and other organisational variables (mediators).

- ***Technological Closeness***: The motive of inter-organisational NPD collaborations is to access technology, organisational capabilities, and other resources that fill an existing gap in the organisation seeking the partnership [Li-Ying et al. 2014; Parraguez and Maier 2012; Song et al. 2012]. By understanding “technology” not only as the machinery and equipment developed, but also as the know-how, tools and processes used in the production of the machinery, equipment, or services, we can include a wider set of considerations under the concept of “technological closeness”. These considerations comprise the match between the technological need of the focal organisation with what the target third party has to offer in terms of technology. Confirming what seems intuitive, previous research has shown that the degree of matching between the technology needs in the focal organisation and the potential technology solutions in the target organisation is an important predictor of success in NPD collaborations [Li-Ying et al. 2014; Littler et al. 1995]. However, the identification of what makes a good technological match, especially in early stages of projects seeking innovative solutions, is not trivial. For example, it is often hard to define upfront the type of technology and know-how that will lead to the desired product or service [Emden et al. 2006; Parraguez and Maier 2012].
- ***Relational Closeness***: Previous collaborations and other interactions between organisations have been frequently described as success factors of future collaborations [Buonansegna 2014; Littler et al. 1995]. The rationale is that previous relations between organisations can reduce search costs as well as other expenses related to setting up new partnerships. These costs include, for example, due diligence and the costs associated with the formation of unsuccessful partnerships.
- ***Geographical Closeness***: The effect of the physical distance between collaboration partners has also been well documented. Everything else equal, geographically close partnerships facilitate the exchange of information and enrich interactions. The effect of geographical distance on collaboration is also known to be non-linear and subject to discrete changes in the modes of transport required, the chances of unexpected encounters, and other contingent organisational and network factors [Whittington and Owen-Smith 2009].
- ***Other Organisational Variables***: While the three previous categories of factors relate with ideas of relative “closeness” between a given set of organisations, there are a number of other measures that can be used to describe characteristics that are intrinsic to each firm. These organisational variables can be thought of as organisational attributes, which, when combined with the attributes of the target organisation, have an effect on the success of a given collaboration. We highlight here three of such organisational variables that have been reported to affect the dynamics of collaborations, are common in the literature, and are easily observable in practice: 1) the different size of the organisations participating in an NPD project (measured by number of employees, sales figures, or other measure of scale), 2) the different types of organisations involved in the NPD project (private business, public sector, research institution, etc.) and 3) the age of the organisations participating in the NPD project. For examples of studies using these organisational variables see [Dooley, Kenny, and Cronin 2015; Farrukh, Fraser, and Gregory 2003; Gesing et al. 2014; Jassawalla and Sashittal 1998; Littler et al. 1995].

B) Success measures for inter-organisational collaboration

This type of variables includes the qualitative and quantitative means used to assess the success of a given collaborative NPD project. Success measures are typically associated with quantitative means to compare the original plans against what actually happened in relation to time, budget and technical requirements. However, these success measures can also include assessments in relation to the degree of absorption of new technologies and capabilities, the strengthening of an industrial relationship, future increases in sales, or any other impact associated with the NPD collaboration [Buonansegna 2014; Li-Ying et al. 2014; Song et al. 2012].

C) Mediators – characteristics of the NPD project

The previously mentioned success factors for inter-organisational collaborations will often be mediated by the characteristics of the NPD project. Here, we highlight three characteristics of NPD projects that previous research suggests as mediators.

- ***Desired Degree of Innovativeness:*** Evidence indicates that there is an inverse relationship between the degree of innovativeness of the NPD project and the overall technological similarity between the organisations engaged in a partnership [Emden et al. 2006; Li-Ying et al. 2014]. In other words, if the NPD project seeks innovative or creative solutions, it is desirable to open the search space for potential technologies and to include areas further away from the core technological expertise of the focal organisation. Similarly, projects with higher ambitions in terms of innovativeness might benefit from exploring solutions of partners that are relationally and geographically more distant [Whittington and Owen-Smith 2009], as this can lead to new solutions outside what is already available in the relational and geographical proximity of the firm. In terms of other organisational variables, previous evidence suggests that diversity of organisational size, type and age also contributes to higher degrees of innovativeness e.g. [Gesing et al. 2014; Reagans and Zuckerman 2001].
- ***Technological Maturity:*** Organisations working on mature and well-understood technologies can step into collaborations that integrate technologies beyond the organisation's immediate proximity, as the risk of failure of such integrations can be mitigated by the technological maturity of the technologies that are being integrated [Littler et al. 1995]. In terms of relational closeness, geographical closeness and other organisational variables, immature technologies can reduce the technical risks of the organisation when partners are relationally and geographically close and sufficiently similar [Buonansegna 2014]. In these cases, the reduction in transactional costs and the increase in agility can be used to mitigate the technological risks of immature technologies.
- ***Time and Budget Constraints:*** The tighter the time and budget constraints, the stronger the need for agility, risk mitigation, and cost reduction. In such cases, NPD collaborations benefit from an approach that seeks technological, relational and geographical closeness as well as similarity in terms of organisational variables between the organisations participating in the NPD project [Emden et al. 2006; Yamakawa, Yang, and Lin 2011].

2.2. Decision-making tools and approaches to support exploration and search of NPD partners

Drawing on extant literature and insights obtained through workshops and interviews organised during the *Net-Sights* projects, we identified that the practice of exploration and search for NPD partners is typically supported by the following tools and approaches:

- ***General purpose search engines:*** Here the user searches for specific keywords. Ranking of the results is typically not transparent and not very customisable.
- ***Specialised search engines:*** Tools where the user searches within specialised databases incorporating patents, receivers of R&D funding, industry directories, technology offers and needs, etc. Ranking and filtering of the results is more transparent and customisable, but time commitment, costs, and required knowledge are also higher.
- ***Structured industrial directories:*** These directories enable the exploration of a number of potential NPD partners. Unfortunately, there are many partially overlapping online industrial directories, each with their own structure and scope. This leads to high search costs and fragmentation.

- **Professional social networks:** Social network platforms such as LinkedIn greatly facilitate partner exploration and search, however the reach of each user is determined by the contacts each user already has. Also, data-exports and manipulation are intentionally limited, making data acquisition and analysis difficult.
- **Open innovation and technology transfer platforms:** An increasing number of online platforms broadcasting technology needs and offers have emerged as response to the calls for higher levels of open innovation. However, given the focus of such platforms on technology challenges and offers, and the anonymity that is typically enforced for technology needs, these platforms are often not directly suitable for the search and exploration of NPD project partners.
- **Offline activities:** Besides online support tools, a number of networking events and workshops are often organised by innovation networks and other support agencies and initiatives. While these are vital spaces for face-to-face interactions, and create opportunities for serendipitous encounters, in isolation they are expensive, hard to scale, and time consuming ways to systematically provide matchmaking support for collaborative NPD projects.

2.3. Gap and focus

While previous research has identified a number of success factors and some mediators for inter-organisational collaborations in NPD projects, those studies have mainly focused on a variable per variable analysis instead of a system-level understanding. Furthermore, most works do not differentiate between different stages of the collaboration process, leaving the stages of partner exploration and search insufficiently characterised. This makes the definition of support that the partner selection process requires difficult.

In terms of decision-making tools and approaches used in industry, we found abundant fragmentation and little or none systematic incorporation of known success factors and mediators. In general, decision-making tools and approaches tend to group around two extremes 1) mostly chance-based approaches, such as networking events, which are good for exploration but time-consuming, hard to scale and control, and often resource inefficient, and 2) more structured search-based approaches, where key parameters about the desired solution need to be known in advance, artificially narrowing down the solution space.

As a result of the previously presented gaps in theory and practice, there is an emerging need at the conceptual level for a framework able to consolidate and integrate the results of previous studies. At the practical level, we need to connect research advances with a data-driven platform, where prescriptive advice provided by existing research is transformed into actionable new insights and contextualised decision-support. In the following section we suggest a framework and a platform to help filling these gaps.

3. A network-based framework to explore and search for new product development partners

Based on the gaps identified, we develop the network based-framework to explore and search for new product development partners. We first position the framework within an overall collaboration funnel, we then present the elements that compose the framework and how they are integrated, and finally, we provide a diagrammatic overview of the framework in action.

3.1. The collaboration funnel

Fraser et al. (2003) describe the collaboration process in four stages: preparation, formation, management, evolution and conclusion. Building on this work, and expanding the first stage, we introduce the collaboration funnel (figure 1). The funnel starts with the stage of NPD partner exploration, and finishes with collaboration outputs and revision. Given the focus of this paper, we provide additional details to the stage of “preparation”, expanding it into “exploration” and “search”.

During the stage of exploration, approaches such as offline activities and industrial directories are useful tools to identify areas where to look during the search stage. In turn, during the search-stage, tools that allow quickly narrowing down and ranking results based on a set of criteria are the ones that are typically more useful. Among these tools we currently find generic as well as specialised search engines. Based on what we know about the need to broaden the search space of technology and partners [Li-Ying et al. 2014], and the importance of avoiding availability bias and anchoring when searching for solutions [Emden et al. 2006], our framework strengthens the support of exploration activities and eases the transition from search to exploration in a systemic and systematic manner.

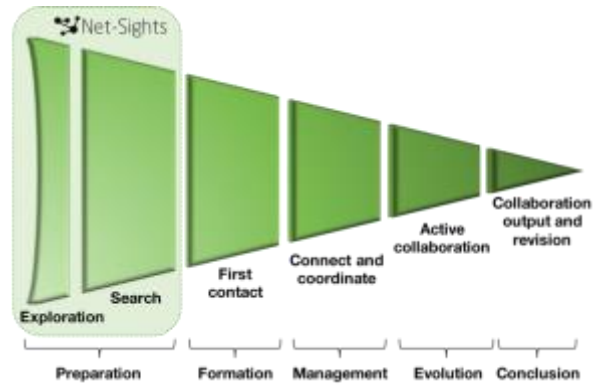


Figure 1. Collaboration funnel
(adapted from [Fraser et al. 2003]).

3.2. Building blocks of the framework

Our framework for partner selection in inter-organisational NPD projects organises the multiple success factors and mediators found in the literature into actionable, measurable, and interconnected building blocks. The success factors are divided into two: “network structure” and “network composition”. In turn, the mediators are divided into the three original categories described in subsection 2.1.

The network approach for exploring and searching NPD project partners is grounded in the idea that all organisations (within analytical and practical boundaries of a given study) can be considered as being part of an overall industrial network containing all potential NPD partners. Such an industrial network is composed of organisations and each organisation has measurable success factors and mediators.

The success factors grouped under network structure are associated with measures that can be used to compute the relative closeness between each pair of organisations. The combination of all the relative closeness measures gives rise to a model that describes the overall network structure of an industry. The success factors grouped under network composition are associated with general organisational variables that act as attributes for each firm. The combination of individual organisational attributes is what gives rise to what we describe as the overall industry network composition.

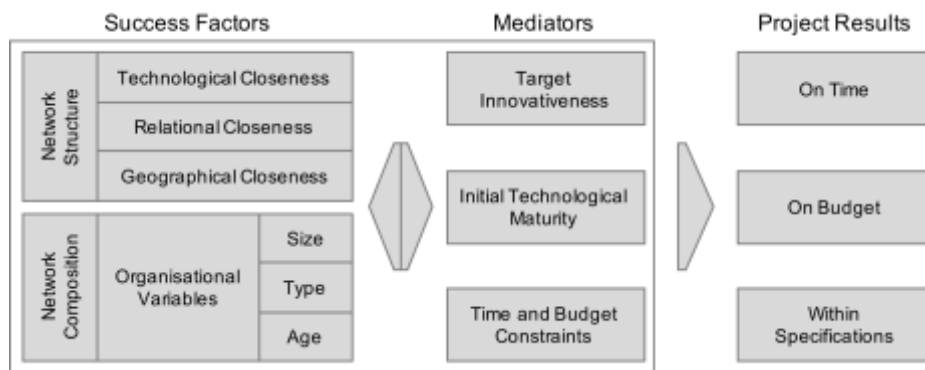


Figure 2. Building blocks of the framework

Technological, relational, and geographical closeness are classified within network structure for two reasons: Firstly, for each pair of organisations in the industrial network under analysis it is possible to quantify a measure of relative closeness related to these factors. Secondly, in isolation, these closeness

measures are frequently used to quantify the structure of industrial networks (e.g. [Parraguez and Maier 2012; Whittington and Owen-Smith 2009; Buonansegna 2014]). General organisational variables such as size, type of organisation, and age are classified within network composition for two reasons: 1) These variables are more suitable to describe characteristics of each firm, not about relations between firms. 2) While it is indeed possible to connect organisations given weighted similarities on size, type, or age, the theoretical grounds to do so are insufficient. In contrast, the use and impact of these variables as organisational attributes (linked to network composition) is in the analysis of industrial networks common practice, following social- and organisational network analysis literature [Wasserman and Faust 1994].

Figure 2 shows the success factors, mediators and project's results organised according to the framework. For each mediator there is a success factor that can be modified by the specific characteristics of the NPD project. The logic of this framework suggests that we can use a set of NPD project characteristics as mediators that serve to modify the effect (direction and strength) of each of the success factors described here. Using the information about the characteristics of the NPD project we can fine-tune the parameters of our exploration and search of NPD partners, focusing on narrower areas of interest of the overall industrial network under analysis. Subsection 3.3 further elaborates this idea with the help of a diagrammatic representation of the framework in action.

3.3. Diagrammatic overview of the proposed framework

Figure 3 describes key steps in the use of our framework to support the exploration and search for NPD project partners. We start by modelling information related to technological, relational and geographical closeness in the form of different layers of an industrial network. Each layer shows all the organisations within the analytical scope embedded in an undirected and weighted network. The connections (also known as links or edges) between each pair of organisations reveal a measure of relative closeness, which defines the strength of the connection in the form of a normalised weight.

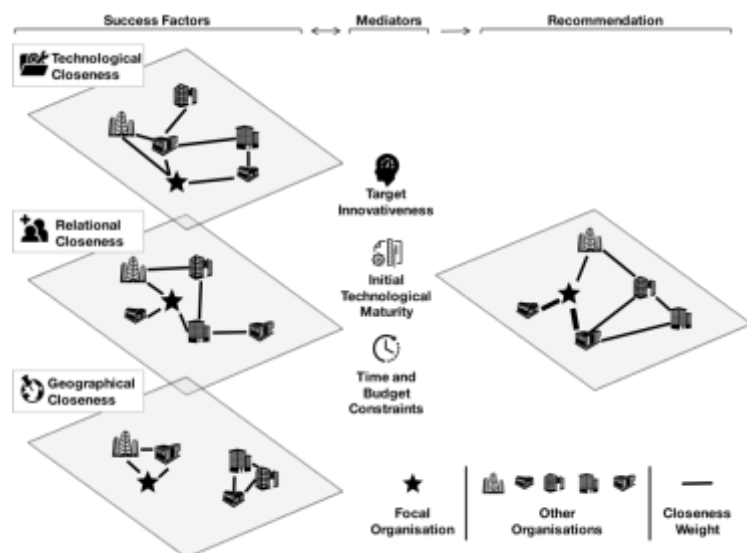


Figure 3. Diagrammatic representation of the framework

Technological closeness is calculated using measurable proxies of technological know-how, such as structured and unstructured text descriptions of each company. For example, unstructured text from the website of each company can be extracted and compared using well-established text similarity metrics. Likewise, categories within industrial directories can be used as links between the firms based on their areas of expertise. **Relational closeness** is calculated using data from sources such as industrial databases showing NPD projects (where two or more companies have already collaborated), hyperlinks between the websites of the organisations under analysis as indicators of relations, and connections in platforms such as LinkedIn and Twitter linking employees from different organisations. Finally, **geographical closeness** is calculated using the coordinates of each organisation and measuring the physical distance between each of them.

Once all closeness measures are calculated, they are captured in a square matrix (organisation x organisation), are weighted, normalised and aggregated, so that we have a weighted matrix for technological, relational and geographical closeness. Those matrices are used as the input to feed the visualisations of the force-directed networks depicted in figure 3. In addition to the network structure based on different types of closeness, each organisation is also associated with the set of attributes that

describe network composition (size, type, and age); attributes that can typically be gathered from industrial databases.

Having the baseline industrial network structure and composition in place, we use the mediators to reweight technological, relational and geographical closeness according to the estimated effect of the intrinsic characteristics of the NPD project on success factors. For example, if the project requires high levels of innovativeness, the initial technological maturity is high and time and budget constraints are also high, we can assign a negative weight to technological closeness, a low but positive weight to relational closeness and a high positive weight to geographical closeness. Following that example, after reweighting the three matrices of closeness, and combining them into one final network representation, the result will show one overall closeness network where organisations will be close in the network and therefore narrowed down as potential NPD project partner candidates, if they are technologically dissimilar and geographically close. Closeness criteria are complemented by criteria selected based on size, type and age; attributes that can be used as filters in relation to the focal organisation or NPD project exploring NPD partners.

4. Application example

In order to illustrate the notion of closeness, figure 4 shows the results of analysing 132 organisations in the Danish cleantech cluster focusing on technological closeness (for details of the methodology see [Parraguez and Maier 2012]). In this simplified exercise we use information about the technology subsector of organisations as proxies to calculate technological closeness. Within the original database, each organisation is categorised into one or more of 68 predefined technology subsectors, which in turn are part of one of seven predefined technology sectors (Intelligent Energy, Energy Efficiency, Heating & Cooling, Water & Environment, Bioenergy, Wind Power, and Solar & Other Renewables). In this network, each connection describes the link between an organisation and one of its technology subsectors. Grey nodes are organisations while coloured nodes are subsectors. Each colour represents one of the seven sectors. Using the network graph presented in figure 4 it is possible to visually estimate the relative distances between organisations and subsectors based on the overall organisation-technology subsector network. The more subsectors are connected to the same set of two organisations, the closer these organisations will be in the model. To move from a visual estimation to a quantitative measure of closeness, direct path distances between each organisation in the graph can be computed. However, more comprehensive approaches based on the centrality nearness matrix can also be applied in order to consider all possible paths and compute the org. x org. closeness matrix (for details see [Stephenson and Zelen 1989; Parraguez 2015, p.136]).

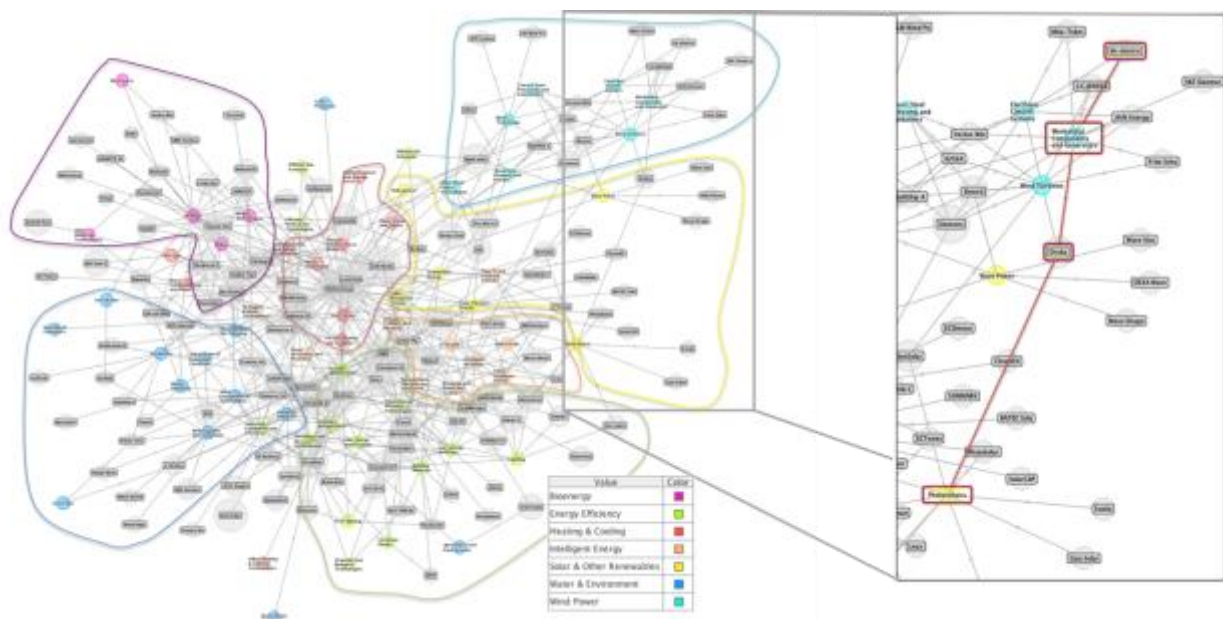


Figure 4. Network displaying technological closeness between Danish cleantech companies (adapted from [Parraguez and Maier, 2012])

Modelling and computing closeness in industrial networks serves not only as a mere intermediary step towards an aggregated analysis, but can also lead to other useful insights. For instance, figure 4 shows how this approach can lead to the identification of natural technology clusters and interfaces between sectors. In this particular industrial network, technology areas such as “Heating and Cooling” and “Intelligent Energy” appear to act as hubs and bridges for other technology areas while “Wind Power” and “Water and Environment” are more specialised technology niches, comparatively less connected to the rest of the industrial network. These insights have direct applications for the organisations in the network as it can help in the identification of potential partners as well as in the discovery of new inter-organisational NPD project opportunities. In figure 4 we have highlighted one such case through a Danish company provider of wind power control solutions, *KK Wind Solutions* (formerly *kk-electronic*), which is highlighted in the top-right corner of the figure. For example, if one of the goals of *KK Wind Solutions* were to develop new products outside the wind power area, using its expertise in wind power control systems to develop photovoltaics solutions, they may need to identify one or more NPD partners that provide technological and market expertise in the solar industry. The right panel in figure 4 shows the shortest route to approach the photovoltaics subsector and the first company to approach may in this case be *Draka*, a cable supplier specialised in complex applications both for the wind power sector as well as in photovoltaics.

5. Conclusion and outlook

In this paper we introduced key elements of a conceptual framework and network-based support platform. This represents the first step of a wider research project that is characterised by its data-driven, network-based and system-level approach to explore and search for partners in inter-organisational new product development (NPD) projects.

The next steps in this research include extensive tests with users, the development of an algorithmic formalisation of the different network views given user feedback, and the validation of the framework and platform. This validation will be carried out within the context of sustainable collaborative production in Denmark, supporting the formation of inter-organisational NPD projects in this industrial setting.

As contributions to industry, we envision the application of the framework and platform to benefit two distinct groups: 1) Companies planning inter-organisational NPD projects, who through the direct use of the developed platform will be able more efficiently and effectively to identify partners for collaboration, and 2) Industry associations, innovation networks, and public agencies who through industry-level network insights will be able to provide better support to companies and to prioritise cluster and industry development efforts. As contribution to academia, from a theoretical standpoint we contribute to filling current research gaps in the early stages of inter-organisational NPD projects through an integrated and empirically grounded framework. From a methodological and practical standpoint, our contribution is twofold: First to support the work of researchers through the creation of an open-source platform that others can use and modify to study the relationship between industrial network architectures and other variables. Second to enable new-data driven research through the release of structured datasets that contain information about Danish industrial networks.

We have identified two limitations in our approach, first, any empirical result is limited by the quality of original data sources and the scope of our project does not allow for validation and additional data acquisition at the level of employees within each organisation. However, the public availability of our data sources and the open-source nature of our tools enable researchers to conduct independent studies. Second, in response to the nature of the available data and to maintain computational simplicity and transparency, we have not incorporated the effect of agency or temporal evolution. In going forward, longitudinal data and the future availability of new methods and tools will allow enriching the model, analyses, and decision-making support presented here.

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