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INNOVATION NETWORKS – APPROACHES TO DERIVE PARTICIPANTS AND RELATIONS SYSTEMATICALLY

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ABSTRACT
Companies do usually not develop highly complex products incorporating extensive product structures on their own. Interoperation beyond the company's borders widens the scope of innovation to innovation networks consisting of various companies and experts aiming at innovative products. Especially customers meet these products in various applications to fulfill their needs. Integration of proper participants in new product development (NPD) furthers the generation of really innovative conceptual designs, products, and services by incorporating specific knowledge and/ or experience. The authors propose several approaches to reveal innovation networks by deriving participants and relations systematically. This framework will be applied to analysis an explorative study comprising 40 innovation projects. NPD process, product, and extended product application set the starting points to condense innovation networks systematically. Case studies illustrate the suggested approaches and demonstrate how awareness about innovation networks facilitates innovation.

Keywords: stakeholder integration, innovation network, new product development.

1 INTRODUCTION
Technical products nowadays often consist of various components. Original equipment manufacturers split up the development of their products and delegate development tasks to suppliers. The supplier may integrate standard components such as screws from the second tier in order to compose modules together with specialized components of his own. Thus, companies do not carry out development of highly complex products on their own. Various experts, partners and suppliers work together to generate added value. For instance project based R&D network comprising heterogeneous partners drive forward innovation as discussed in [1, 2].
Products mostly provide a means to fulfill several applications. Modular product structure as for example obtained by a kind of platform concept for small power tools comprise e.g. a power and motor unit which is able to connect to several specific devices for drilling, cutting, and sawing. In purely electronic products such as mobile devices software enables various functionalities such as telephone, music player, navigation device. In both cases the products fit a bunch of applications.
On the one hand innovation networks consist of interlinked NPD processes and participants within the company and across companies' borders as summarized in [3]. On the other hand product application leads to a specific set of users and customers that receive the product and generate any kind of value by applying the product.

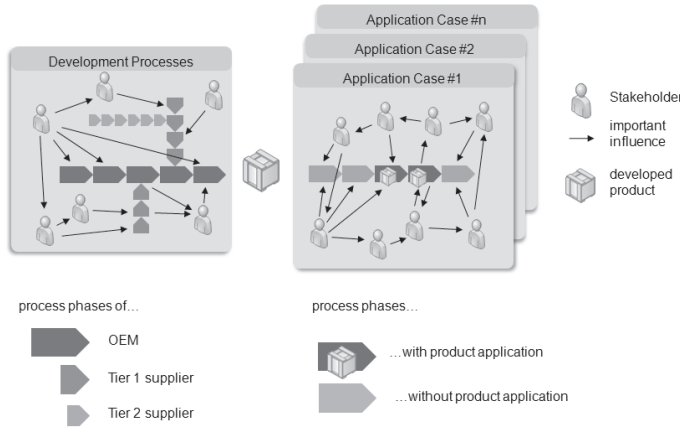

Figure 1. Innovation network with interdigitating processes and stakeholders

Figure 1 depicts an innovation network comprising interlinked development processes which result in a product, which fulfills several applications. Innovation networks consist of a complex tracery of plural co-operation partners, that agree upon a willful, lasting, and distributed and interactive cooperation at innovating [4]. Participants surround both the development and application phase of the product. The innovation network consists of nodes which represent participants and edges which state their interrelations.

It is yet to detail the starting points and approaches to uncover an innovation network to support NPD. Within this paper the authors present several approaches to derive participants (nodes) and relations (edges) of innovation networks systematically.

Section 2 provides background information about definitions, theories and the research question this work addresses. Section 3 contains methods of revealing innovation networks embracing product development and the product application systematically. Section 4 details case studies to illustrate the suggested approaches. Section 5 presents the data interpretation. Section 6 summarizes the outcome of the work and presents an outlook to future work.

2 BACKGROUND

This section introduces the definitions of the term *application* and the term *extended application process*. It provides an overview of stakeholder theory and furthermore illustrates the research question of this work.

The product lifecycle consists of several phases, whereas development is only a small fraction[5]. In the phases *use* and *service* the user gets in contact with the product and is interacting with his environment by applying the product. *Product application* is then according to [6] the activity that emerges from the interaction between product and stakeholder within a certain context. The application itself is determined by preceding process steps that lead to or demand for the application of the product. The extended application process comprises the appearance and determination of the product application, and process phases beyond product application as discussed in [3]. It contains: (1) the process causing the application, (2) stakeholders including their characteristics, (3) process dependent stakeholder involvement, and (4) additionally technical requirements characterizing the application. The EAP enables to gather deep understanding of the constraints surrounding the product application.

A means to analyze and reason about business and society relationships is the stakeholder concept [7, 8]. Much effort has been taken to extend the stakeholder theory, see e.g. [9-13]. Generally a stake represents either an interest or a share in an undertaking or a claim [7]. The latter one comprises a demand for something due or believed to be due. A stakeholder has one or more of these kinds of stakes. The stakeholder is defined as an individual or a group in the organization or a company [7, 8]. In the context of innovation networks a stakeholder is supposed to be a participant in either product development or product application or both [3]. The highly dynamic character of innovation processes

and highly interfering relations among various stakeholders challenge the application of stakeholder theory in innovation networks.
One possible way of enhancing NPD is the systematic utilization of innovation networks [see 14, 15]. To include knowledge and experience of participants, one needs to identify them. Relations connect participants and support determination of further ones to gain a multi-facetted point of view of innovation networks. An explorative study on innovation projects is currently being carried out, comprising 40 innovation projects in German industry. The methods presented in this paper are a means to reveal innovation networks, of which the project team analyzes the structure and dynamics of innovation networks in general. Based on this, the research focuses on integrating the customer systematically in early phases of the NPD, as the customer‘s voice is here still underrepresented [16].

3 METHODS

As follows the authors propose several approaches based on specific starting points to unhide innovation networks systematically. They have been derived by analysis of several innovation projects and enable a structured manner of establishing innovation networks as depicted in Fig.2: (1) *NPD process*, (2) the *product*, and the (3) *extended application process*.

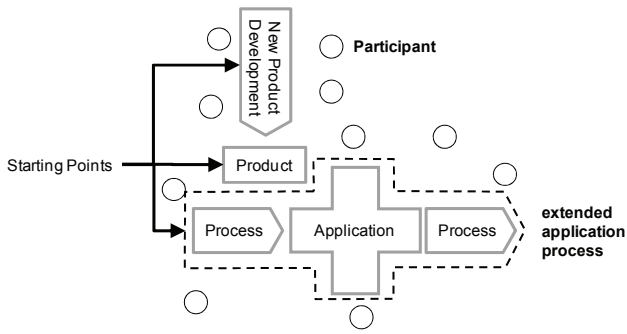

Figure 2. Starting points for identification of innovation networks

Each starting point enables to obtain a particular focus on the innovation network and leads to a specific result. The resulting structure supports the understanding of the innovation network, nevertheless only a combination of the three approaches supports a multifaceted, holistic view of the innovation network (see Fig. 3).

Starting Point	Purpose
NPD Process	Get to know the NPD process, uncover relations and improve the process
Product	Become aware of several product applications
Extended Application Process	Understand a specific product application deeply, identify customers‘ motivation and needs

Figure 3. Purpose and Starting point for innovation network analysis

As follows the suggested approaches are explained in detail. Each approach is described by a purpose, requirements, and a description.

3.1 NPD based innovation network analysis

A NPD based analysis of innovation networks supports to get to know the NPD process, to uncover stakeholder relations and to improve the process. A deep understanding of the development process (formally/ informally referred to), the participants (departments, experts), and their time dependent interrelations (informal meetings, dependencies due to data) is not always self evident. Development projects carried out among several partners, service providers or dependencies within a supply chain complicate to comprehend the NPD project at a glance. Innovation network analysis based on the

development process furthers the awareness of the relationship among process stakeholders and enables to improve the process (see Fig. 4).

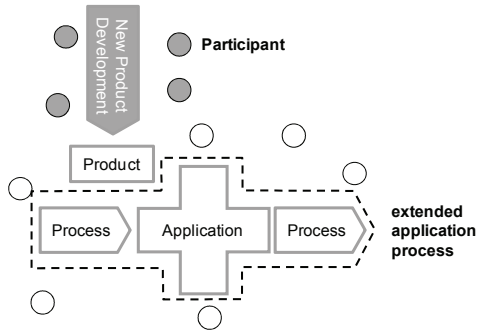

Figure 4. NPD Process based Stakeholder analysis

The review of an already finished innovation project unhides these relations retrospectively to support project reflection and conclusion of lessons learned. Consideration of still running projects supports managing the project prospectively.
The first step identifies stakeholders determining process phases strongly. Getting to know time dependent stakeholder interactions also among stakeholders which do not determine the process phase directly enables to draw stakeholder interaction maps as discussed in [17] and depicted in Fig. 5.

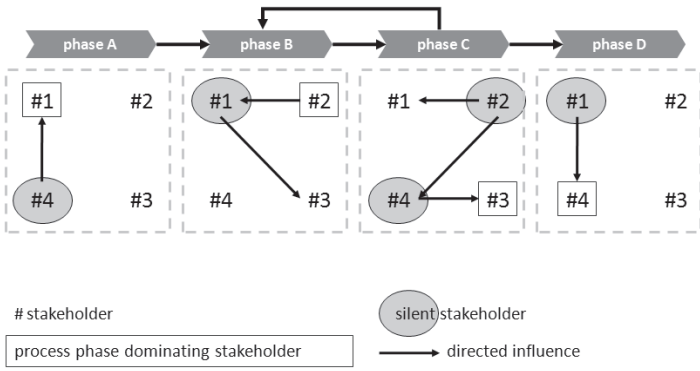

Figure 5. Example of an Stakeholder interaction map [17]

Here time dependent directed interrelations among stakeholders are depicted and enable to identify stakeholder interaction chains. Connecting beginning and ending of the chain (see Fig. 5 phase B and C) shortens the communication among stakeholders and supports process improvement. It becomes reasonable to balance the project according to predefined constraints.

3.2 Product based innovation network analysis

Product based analysis of innovation networks reveals several product applications. This supports the understanding of how products are applied and reveals use cases. Feeding back particular knowledge about the application to the development process besides technical specifications furthers a holistic view on the product (see Fig. 6).

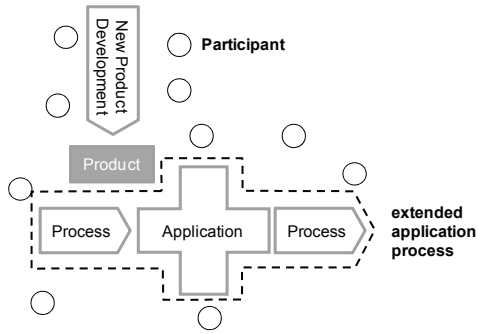

Figure 6. Product based Stakeholder analysis

This approach is feasible when taking an existing product for granted as starting point. One specific product may not only be applied in one application, but in several ones as depicted in Fig. 7.

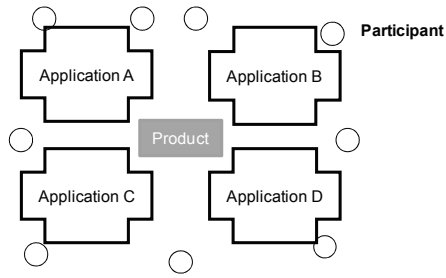

Figure 7. One Product fitting several applications

When several applications are identified, determination and interview of stakeholders takes place. Maybe stakeholders may interlink several applications. The identified constraints, requirements, and technical specifications enrich the NPD process and enable to balance specific applications in redesign or NPD e.g. conceptual product design phase. Due to identification of product applications this approach can be considered *swimming downriver* the innovation network starting from the product, via product application, to the user.
Detailing the understanding of particular applications requires the approach based on the EAP as discussed as follows, in order to identify the emergence of the application.

3.3 Extended application process (EAP) based innovation network analysis

An EAP based analysis of innovation networks supports to understand one application deeply in order to question existing products completely, and design new products application driven. Not only the product application itself but understanding the EAP completely enables to enrich the NPD process of products/ system solutions fitting customers' needs (see Fig. 8).

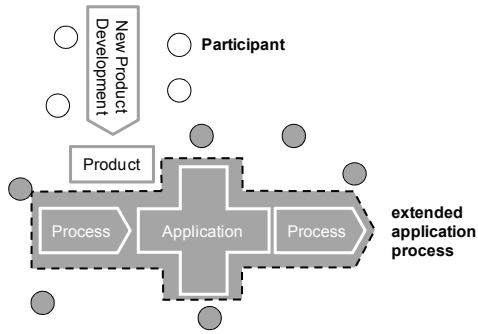

Figure 8. Extended Application Process based Stakeholder Analysis

Questioning the existing product completely shapes this approach. Several products may satisfy one particular application in cooperation (see Fig. 9).

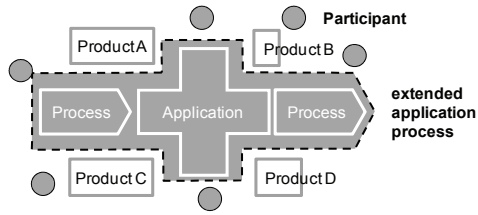

Figure 9. Several Products satisfy (in cooperation) one particular application

Exploration of the EAP, which results in the application itself gathers a deep understanding of root cause as impetus for the NPD process. Get to know the stakeholders of the EAP, understand how they shape the EAP by time dependent interactions among the process phases and among each other by analysis of their needs, requirements, technical specifications, process coverage, and process participation [17]. Together with technical constraints circumstancing the application these organizational information enriches the NPD process as described in [3]:
(1) These characteristics enable the weighting of requirements to support the NPD process itself. (2) Activity and range of participation characterize stakeholders that are to be integrated in the NPD process. (3) Moreover entry gates to place products addressing the key stakeholders in the EAP occur.
Swimming upriver the innovation network beginning from the EAP to NPD characterizes this approach.

4 RESULT

This section presents results for each proposed starting point to uncover innovation networks. Case studies carried out together with various industrial and academic partners illustrate the particular approaches.

4.1 NPD Process based innovation network analysis

A cross university NPD project (ETH Zurich, FHS St.Gallen, and ZHdK Zurich [Switzerland], TUM [Germany]) enabled to carry out a case study in a confined environment (Swiss University Project). The students performed a complete NPD process from strategic planning to a physical prototype within 6 months in the topic of white goods (see Fig 10).

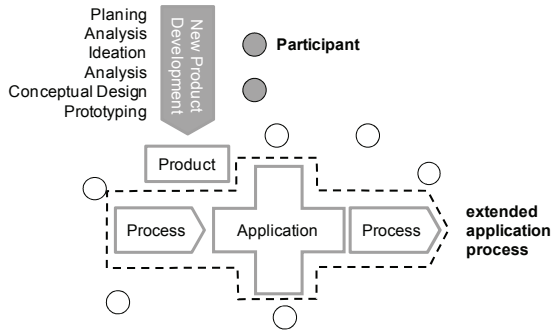

Figure 10. Process Model applied by SUIP (Swiss University Project)

The team leader generated a detailed process documentation consisting of stakeholders and stakeholder interactions per process phase. For the overall project a process description results as it is depicted exemplarily in Figure 11.

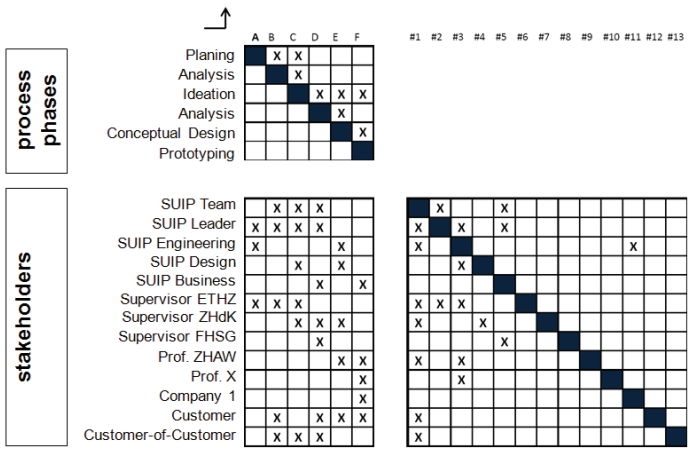

Figure 11. Multiple Domain Matrix describing the NPD process (process phases and stakeholders)

The Multiple Domain Matrix depicts the domains process phases and stakeholders. The overall project is shown, without displaying time dependent interactions between process phases and stakeholders. Line Elements influences column element.

4.2 Product based innovation network analysis

A short case study exemplifies the product focused analysis in innovation networks. A NPD project carried out in cooperation with industry focused the redesign of a small hand-guided power tool. Two main applications characterize the tool (see Fig. 12).

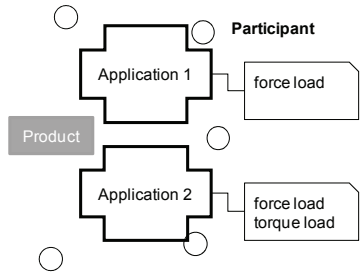

Figure 12. Two applications of an electric power tool

They differ mainly in the specific load cases, other constraints are quite equal. In the first one only force load stresses the power tool, in the second one additionally torque load may occur. The existing power tool required refitting the device currently in use for each application. Several interviews and observations of usage have been carried out in order to gain deep understanding of these two applications from various points of views. A completely new conceptual design to cover both applications without mounting additional devices resulted finally.

4.3 Extended application process (EAP) based innovation network analysis

In this case study the product itself was questioned completely by carrying out an EAP based innovation network analysis. As described in detail in [3] together with a major industrial partner the EAP supports a deeper understanding of the application itself.

Starting point of this case study is the application of power tools within the construction of a fixed asset. Due to experience and touch to market the industrial partner recognized a lack of satisfaction of the application by existing products. The management decided to overcome the limitations of the existing products by innovating. Therefore the company's experts questioned completely both the existing products and solutions to fulfill this application. An EAP was explored, to understand the root causes that determined the emergence and circumstances of this application (see Fig. 13).

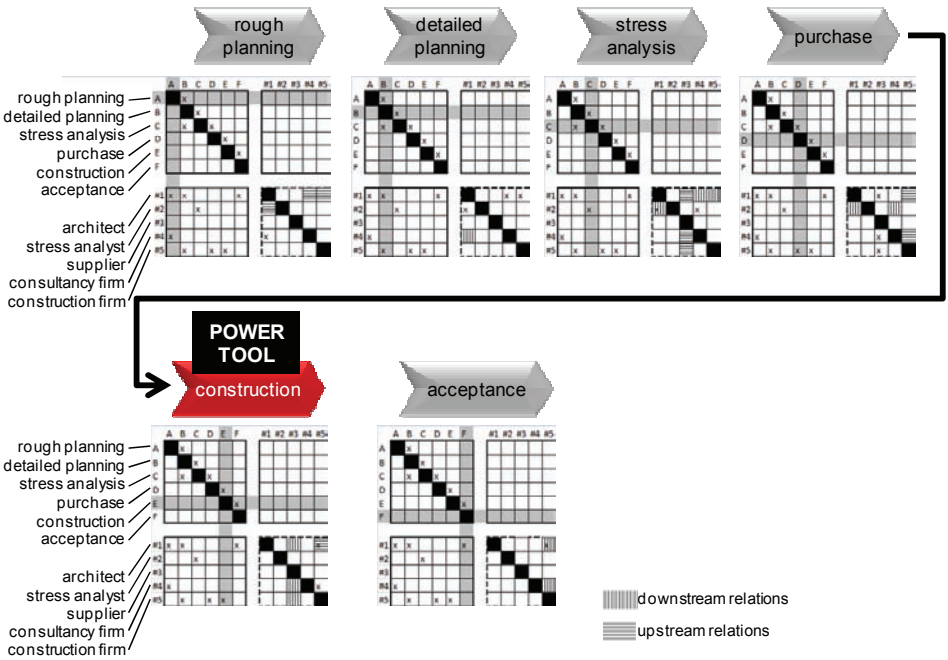

Figure 13. Extended Application Process in planning a fixed asset

The MDM contains a snapshot of the process comprising the application of power tools the in generation of a fixed asset depicting the domains process phases and stakeholders. The order of process steps, as well as the main stakeholders driving process steps, stakeholder influencing each other and process steps affecting stakeholders characterizes the process. Detailed analysis revealed unknown stakeholders, and the importance of specific stakeholders who need to be integrated in the NPD process.

5 DISCUSSION AND INTERPRETATION

Several case studies highlight the capability and applicability of the presented methods to uncover innovation networks beginning from particular starting points. An innovation project carried out by students and supervised by several universities illustrates the *NPD based innovation network analysis*. Within a NPD and research project together with an industrial partner a *product based innovation network analysis* led to an innovative conceptual design of a hand-guided power toll. The cooperation with a major industrial partner enabled to carry out a detailed *extended application process based innovation network analysis* in building a fixed asset. The case study reveals an innovation network starting from the EAP of an electric power tool.

5.1 NPD process based innovation network analysis

Reflecting the analysis of stakeholder interactions in the cross university NPD projects identifies the dominant role of the industrial design student. The team consisted of two students of mechanical engineering, one student of business administration, and one student of industrial design. After 6 months the team presented a physical prototype to prove their innovative concept, and besides this a business plan including a vision of the product. The student of industrial design dominated the project directly and indirectly by influencing other stakeholders. E.g. in the ideation only a view alternative solutions have been generated, because the ones already found fitted the esthetic industrial design concept very well. When the team built the real prototype they recognized that the chosen solution did not work properly in its characteristics of shape the industrial design student had specified. The team has not recognized during the project this enormous influence in vital phases, but reflecting the process finally revealed this matter of fact exemplarily. Even the industrial design student was really surprised about his influence during the project work. Within the matrix representation process phases are not weighted, thus the decisive role of the ideation phase is not depicted.
The NPD process based analysis grounds on analyzing a project retrospectively. Nonetheless it also may support currently running projects by lessons learned from similar projects or even by revealing interdependencies of hidden stakeholder interactions. Process reflection apart from daily business proves a proper means to improve behavior and raise attention.

5.2 Product based innovation network analysis

The analysis results in knowledge about several product applications and detailed technical specifications. The industrial partner did not gain a perspective completely differing from the one before. Former products have specially been designed for one application, and so did the competitors. But craftsmen did not make use of the product “properly” because it was too annoying to change it every time they change the application. Changing the application could occur several times an hour. The team generated completely new conceptual ideas that could integrate the two main applications in one product shape.
Managing product variants plays a major role in the product based analysis of innovation networks. Product architecture as well as marketing constraints need to be considered. Nonetheless the awareness of specific product applications furthers the understanding of the product and thus supports NPD processes.

5.3 Extended application process (EAP) based innovation network analysis

The top management identified a lack of products fitting the focused application perfectly. Several interviews have been conducted in Europe and US, and revealed major differences in fulfilling the application. Legislature and local habits determined accomplishing the application. The exploration of the EAP of using an electric power tool for building a fixed asset enables to cluster the regional applications and to focus on a target market. It sets the base to weight stakeholders’ requirements besides technical specifications to support the NPD process itself. Several innovative conceptual

product designs fitting the observed application from a holistic point of view result. The stakeholders' characteristics also enable the integration of stakeholders to specific steps of the NPD process in an extent never been before.
Talking to experts dealing with specific products intensively may not reveal the EAP due to their mental fixation to the product itself. The awareness of the application instead is the base to apply this approach consequently. During expert talks new interview partners may occur to cover particular process steps more intensively than the recent experts. The decision when an EAP is completely identified depends on the focus of the NPD project.

6 CONCLUSION AND FUTURE WORK

This paper distinguishes several starting points for revealing innovation networks comprising product development and application systematically: (1) the *NPD process*, (2) the *product*, and (3) the *extended application process*. Each approach addresses a specific purpose in revealing innovation networks. The suggested starting points and approaches enable to gain different perspectives with varying intensity and focuses when identifying innovation networks. The description of the approaches contains purpose, requirements, and a description.
The *NPD process* enables to identify stakeholders and their time dependent interrelations in order to improve the process. The *product* furthers to get to know several different product applications and weighting these when deriving new products. Due to identification of product applications this approach can be considered *swimming downriver* the innovation network starting from the product, via product application, to the user. The *extended application process* supports a deep understanding of one particular product application by embracing process phases that lead to or demand for the product application as well as including process steps beyond product application, and customers' motivation and needs. Products fitting the application result responding to vital stakeholders. *Swimming upriver* the innovation network beginning from the extended application process to NPD characterizes this approach. Case studies have been carried out with academic and industrial partners and illustrate the approaches. Nevertheless the question is still to answer, whether additional starting points for systematic identification of innovation networks exist. Moreover the author could not yet present a coherent case incorporating the three proposed methods.
As a next step several case studies will set up a database of innovation networks in the near future. A further research objective will be the strategic utilization of identified innovation networks, to strengthen the output of innovative and commercially successful products.

7 ACKNOWLEDGEMENT

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REFERENCES

1. Tijssen, R.J.M., *Quantitative Assessment of large heterogeneous R&D networks: The case of process engineering in the Netherlands.* Research Policy, 1998. **26**(7-8): p. 791-809.
2. Cliquet, G., *Innovation management within the plural form network.* , in *EMNet-Conference on "Economics and Management of Franchising Networks"*. 2003: Vienna, Austria.
3. Kain, A., et al., *A method to identify relevant stakeholders to be integrated in New Product Development processes*, in *Research into Design, supporting multiple facets of product development*, A. Chakrabarti, Editor. 2009, Research Publishing Service: Bangalore, India. p. 191-198.
4. Hauschildt, J. and S. Salomo, *Innovationsmanagement*. 4 ed. Vahlens Handbücher der Wirtschafts- und Sozialwissenschaften. 2007, München: Franz Vahlen. 635.
5. Ulrich, K.T. and S.D. Eppinger, *Product Design and Development*. 2008: Irwin McGraw-Hill.
6. Robotham, A.J. and M. Guldbrandsen, *What is the new paradigm in product quality?*, in *NordDesign*. 2000: Lyngby, Denmark.
7. Buchholtz, A.K. and A.B. Caroll, *Business and Society*. 7 ed. International Student Edition. 2009: South-Western.
8. Freeman, R.E., *Strategic Management*. 1984, Boston, USA: Pitman Publishing Inc.

9. de Vries, H., H. Verheul, and H. Willemse, *Stakeholder Identification in IT Standardization Processes*, in *International Conference on Information Systems, Workshop on Standard Making: A Critical Research Frontier for Information Systems*, J.L. King and K. Lyytinen, Editors. 2003: Seattle, USA. p. 92-107.
10. Laplume, A.O., K. Sonpar, and R.A. Litz, *Stakeholder Theory: Reviewing a Theory That Moves Us.* Journal of Management, 2008. **34**: p. 1152-1189.
11. Mitchell, R.K., B.R. Agle, and D.J. Wood, *Towards a Theory of Stakeholder Identification and Salience: Defining the Principle of Who and What Really Counts.* Academy of Management Review, 1997. **22**(4): p. 853-886.
12. Rodon, J., J. Ramis-Pujol, and E. Christiaanse, *A Process-Stakeholder Analysis of B2B Industry Standardisation.* Journal of Enterprise Information Management, 2007. **20**(1): p. 83-95.
13. Schmeer, K., *Stakeholder Analysis Guidelines*, in *Policy Toolkit for Strengthening Health. Sector Reform*. 1999, Abt Associates, Inc.: Bethesda, MD.
14. Bauer, R., *Gescheiterte Innovationen: Fehlschläge und technologischer Wandel*. 2006, Frankfurt/New York: Campus.
15. von Hippel, E., *Horizontal innovation networks — by and for users.* Industrial and Corporate Change, 2007. **16**(2): p. 293–315.
16. Kirner, E., C. Dreher, and S. Maloca, eds. *Möglichkeiten zur Innovationsbeschleunigung aus Sicht der Unternehmen*. Fokus Innovation. Kräfte bündeln – Prozesse beschleunigen, ed. H.-J. Bullinger. 2005, Hanser: München, Germany.
17. Kain, A., et al. *An Approach to Model Time Dependent Process-Stakeholder Networks*. in *10th International DSM Conference*. 2008. Stockholm: Hansa.

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