

Philipp Rittershaus

Fostering start-ups in the chemical sector through the joint support offered by seed funds and established companies

Magnus Tottie, Thomas Lager and Sofia Nordqvist

**From customer understanding to product understanding:
Collaboration with industrial lead users in a B2B context**

Martin Schwemmer and Annemarie Kübler

The logistics profile of the German chemical industry

■ Editorial Board

Editor-in-Chief

Prof. Dr. Jens Leker, Institute of Business Administration at the Department of Chemistry and Pharmacy, University of Münster, Germany

Editors

Prof. Dr. Mattia Bianchi, Dr. Clive-Steven Curran, Prof. Dr. Federico Frattini, Dr. Carsten Gelhard, Lars Hahn, Prof. Dr. Sebastian Kortmann, Prof. Dr. Thomas Lager, Dr. Stefan Picker, Dr. Carsten Schaffer, Prof. Dr. Stefan Seeger

Executive Editors

Birte Golembiewski
Ruth Herrmann

■ Subscription

The Journal of Business Chemistry (ISSN 1613-9623) is published every four months by the Institute of Business Administration at the Department of Chemistry and Pharmacy, University of Münster.

Online-Subscription is possible at:
subscription@businesschemistry.org.
The articles are available for download free of charge at www.businesschemistry.org.

■ Aims and Scope

The Journal of Business Chemistry examines issues associated with leadership and management for chemists and managers in chemical research or industry. This journal is devoted to the improvement and development of the field of business chemistry.

The Journal of Business Chemistry offers a means for researchers and practitioners to present their results in an international forum.

■ Abstracting and Indexing

The Journal of Business Chemistry is covered by

the following abstracting and indexing services:

- EBSCO Publishing (www.ebsco.com)
- Hamburg Institute of International Economics (online databases and print archive)
- German National Library of Economics
- Chemical Business NewsBase (CBNB) by Elsevier Engineering Information, Inc.

■ Copyright

Copyright © 2016 Institute of Business Administration, University of Münster

All rights reserved. No part of this publication may be reproduced or transmitted, in any form or by any means, electronically, mechanically, by photo-copying, recording, scanning or otherwise, except as described below, without the permission in writing of the publisher.

Copying of articles is not permitted except for personal and internal use, to the extent permitted by national copyright law. Requests for permission should be addressed to the publisher.

Statements and opinions expressed in the articles and essays are those of the individual contributors and not the statements and opinions of the Institute of Business Administration, University of Münster. The Institute and the University of Münster assume no responsibility or liability for any damage or injury to persons or property arising out of the use of any materials, instructions, methods or ideas contained herein. The Institute and the University of Münster, expressly disclaim any implied warranties or merchantability or fit for a particular purpose. If expert assistance is required, the services of a competent professional person should be sought.

■ Publisher

The Journal of Business Chemistry (ISSN 1613-9623) is published by the Institute of Business Administration at the Department of Chemistry and Pharmacy, University of Münster, Leonardo-Campus 1, 48149 Münster, Germany.

Contents

Letter from the Editors

Commentary

Fostering start-ups in the chemical sector through the joint support of-
fered by seed funds and established companies

Philipp Rittershaus..... 60

Research Paper

From customer understanding to product understanding: Collabora-
tion with industrial lead users in a B2B context

Magnus Tottie, Thomas Lager and Sofia

Nordqvist..... 64

Practitioner's Section

The logistics profile of the German chemical industry

Martin Schwemmer and Annemarie

Kübler..... 80

Letter from the Editors

Collaboration is key

Nowadays, the chemical industry faces a variety of challenges coming along with current and future developments and the need to satisfy the associated changing demands of different stakeholder groups. Since companies only have limited possibilities to provide all required abilities and capacities by themselves, pursuing cooperative exchange with stakeholders evolves to be a key competence. Companies benefit from collaborating due to the access to external knowledge and technologies (in new fields) and might thus be able to shape industry developments by taking early action. In the recent past, chemical companies have already recognized the high importance of collaborating and thus increased their range of activities. Exemplary interfaces are funding and supporting start-ups, integrating customers and suppliers in the product development process or handling changes and mutual interdependencies with related industrial sectors. The present issue comprises articles reflecting the industry's formation of different forms of relationships as well as their emerging benefits and consequences.

The first article of this issue is a commentary by Philipp Rittershaus and addresses the topic of "Fostering start-ups in the chemical sector through the joint support offered by seed funds and established companies". The interactions between start-ups, investment funds and established companies active in the chemical sector are described and the resulting benefits for each partner are highlighted.

The research paper "From customer understanding to product understanding: collaboration with industrial lead users in a B2B context" by Magnus Tottie, Thomas Lager and Sofia Nordqvist conducts a single case study examining the co-development of a product with lead users. The fuzzy front end of the product development process at LKAB, a world-leading producer of processed iron ore products, is optimized by applying a modified Quality Function Deployment methodology and the integration of lead users, resulting in an improved knowledge-based platform for new product and process concepts.

"The logistics profile of the German chemical industry" is our article for the practitioner's section. The authors Martin Schwemmer and Annemarie Kübler provide basic data as well as associated conclusions on the current status of the chemical logistics sector in Germany. The article presents logistics service providers specialized in the German chemical industry, special requirements for handling chemical goods as well as the geographical clusters of logistics service providers in Germany.

Please enjoy reading the second issue of the thirteenth volume of the Journal of Business Chemistry. We are grateful for the support of all authors and reviewers for this new issue. If you have any comments or suggestions, please do not hesitate to contact us at contact@businesschemistry.org.

Birte Golembiewski Ruth Herrmann
(Executive Editor) (Executive Editor)

Commentary

Fostering start-ups in the chemical sector through the joint support offered by seed funds and established companies

Philipp Rittershaus*

* High-Tech Gründerfonds Management GmbH, Schlegelstrasse 2, 53113 Bonn, p.rittershaus@htgf.de

The processes in the chemical industry are highly efficient and have been optimized and scaled up over many years. In short, the chemical sector is a mature industry. This mature industry has a highly diversified portfolio of products and raw materials. Maximum efficiency and huge volumes, as well as capital-intensive installations through to integrated production sites play a key role for the industry.

1 Options of external innovation within the chemical industry

Given the huge production volumes in question, even minor improvements can represent a major advantage. A small amount of process optimization and innovation can provide a major boost to chemical companies and give them an edge on the market. In addition, there is a high level of price sensitivity and competitive pressures due to a diverse range of factors. Environmental requirements have become tougher, with material efficiency having to be improved, energy consumption decreased and production downtime reduced. These are tasks that chemical companies face day in day out. These tasks are being addressed by large internal R&D capacities of the corporations that know the own processes best. Therefore: Does the chemical industry need external innovation at all? The answer is yes, it does.

In a nutshell, external innovations enable chemical companies to drive forward their business and secure advantages on the market. The companies are seeking new ways to optimize production. These alternative approaches or new sensors can lead to a reduction in costs. In addition, they are also looking for options to expand their product portfolio. New technical capabilities and the emerging opportunities due to the digital transformation, the impact of which will be felt in almost all areas, represent an additional dynamic that companies face and

that expertise is unlikely being present in-house. But still: all external innovations need to target the specific situation of the chemical industry and facilitate efficient implementation into existing processes of industrial scale.

2 Hurdles to technology transfer and the road to a successful commercialization

The transfer of technology from academic ideas to innovative industrial-scale implementation is often an arduous task. Thus, realization expertise and start-up capital are required. Seed funds such as High-Tech Gründerfonds (HTGF) can forge this link by providing start-up capital and support structures – in a sense, an “entrepreneurial toolbox”.

New technologies are e.g. being developed at universities at a constant rate. At the early development stage, application-based funding can be provided through to “Proof of Principle”, with it supporting commercialization preparations in a protected environment. However, these technologies need to have reached a certain stage of maturity before the technology transfer process is complete and they qualify for commercial use.

This further development and maturity of the technology through to “Proof of Concept”, prototypes or initial scaling stages typically takes place at start-ups. What defines these spin-off technology firms is the fact that they own or have access to a proprietary technology that is to be successfully launched on the market as an application following a phase of validation and scaling.

The path from lab to industrial scale is fraught with numerous challenges. In addition to the development of the technological asset, a transfer into the commercial sector requires additional support in the form of venture-capital financing. In addition, the successful transfer of technology from the field of academic or commercial research frequently requires close ties to established companies as

cooperation partners or users of the technology. This is true for the entire spectrum of chemical focused start-ups, as has previously been illustrated for the industrial biotechnology segment (Festel and Rittershaus, 2014).

To overcome technology transfer hurdles, start-ups require start-up capital as well as a reliable network that provides specialist expertise on realization. The journey towards successful commercialization can be initiated by strong investment partners that provide start-ups with the required capital, offer support with the help of successful methods, and maintain a reliable network of industry partners.

The next sections will detail a number of factors that support successful interaction between start-ups, public-sector support, early-stage venture capital within a mature industry, using the example of HTGF.

3 Sources of capital for start-ups

Before a technological development has reached the necessary level of technical and commercial maturity and market entry has been established, there are different sources of capital for the various phases, as illustrated in figure 1.

In the early stages of a business, start-up capital is mainly provided by business angels, as well as specialist seed funds, in addition to the founders' own funds. Institutional venture capital investors tend to join at a later stage with further maturity, leaving a gap for the early development stages. Another source of capital is provided by established corporations. Their financing is often being based on existing cooperation, indicating a strategic fit between the funded start-up and the firm's current and future portfolio.

4 Value added by corporations

Alongside capital, there is further support provided by funds or corporations that will add value to the technology firms (figure 2). Expertise on industrial processes exists in the established companies, which also enable a scalable market entry, the market itself or licensing options for the technology. In addition, an increasing number of established companies also have the ability to invest at an early stage through the corporate venture arms they have set up. The need of capital and specialist expertise by start-ups can therefore both be provided by established companies which ties in with the mutual benefits enjoyed. This combination is

Figure 1 Stages of financing and typical sources of capital for chemistry-related start-up companies.

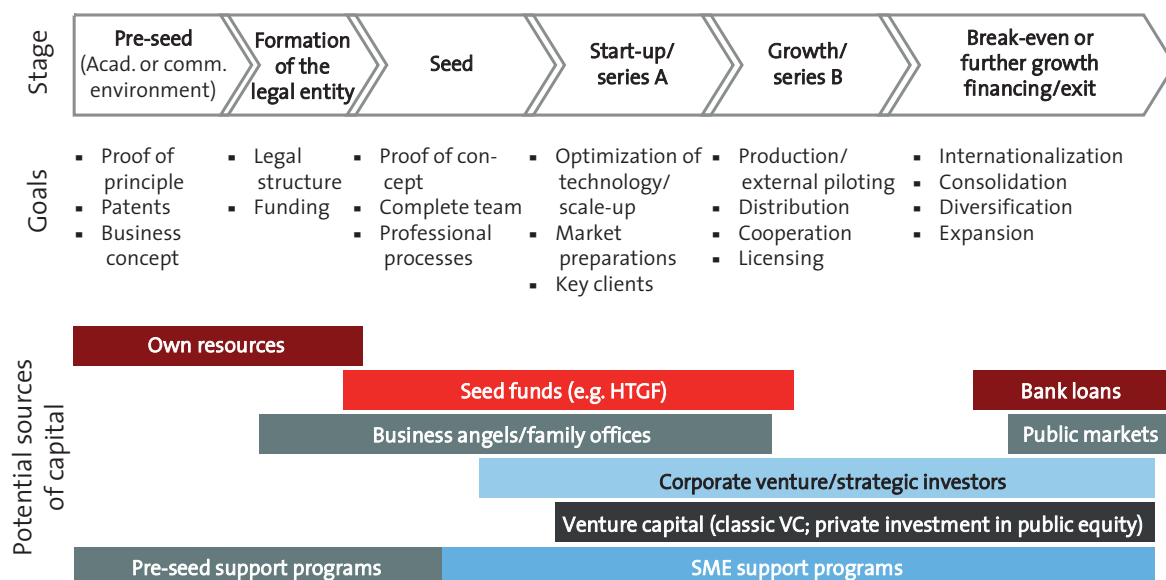
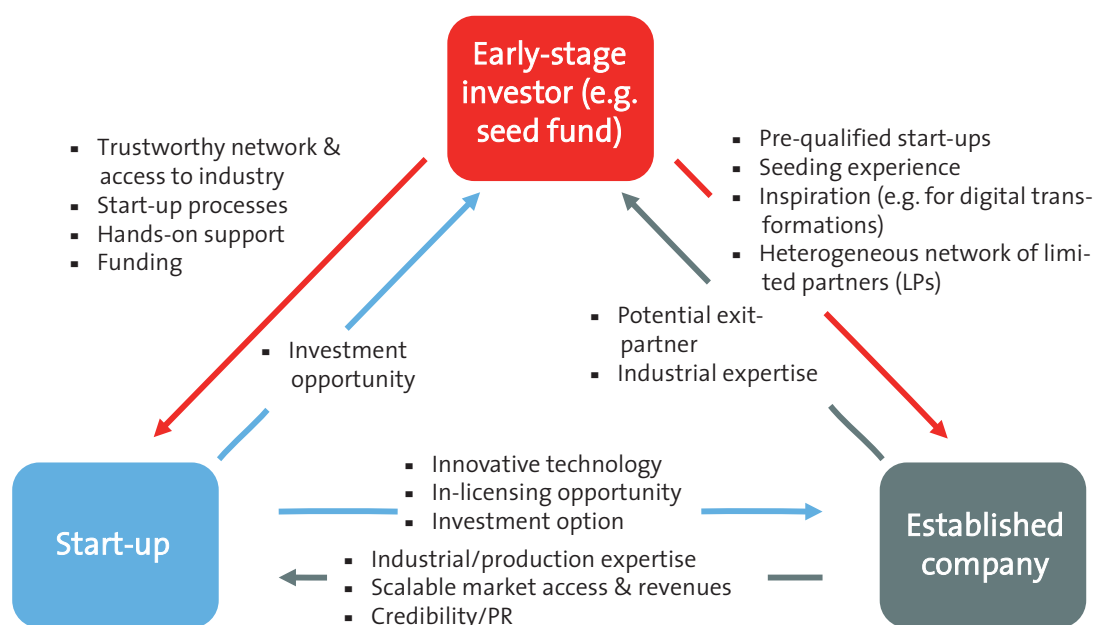


Figure 2 Combination of corporation, seed fund and start-up offers and needs.



also reflected in the sources of capital available at various stages during the preparation and maturity phases of a chemical start-up. However, the financing activities of established companies rather focus on acquisitions of complementing more mature tech-companies than fostering very young ones. Therefore, the initial hurdles that need to be cleared for an established company to invest are very high for start-ups that only find themselves in an early development stage.

5 Active support provided by early-phase investors

Seed investors such as HTGF have specialized in overcoming these hurdles by providing active support and establishing professional processes in the initial phase. They take on a high degree of risk. However, their involvement at such a stage enables them to make a significant difference in the company's performance, even with limited capital investment. They complement this limited level of capital investment with active support structures in the form of an "entrepreneurial toolbox".

They offer hands-on support, especially in the initial phase, as there can be many different iterations before a strategically valid business model is found. Management and documentation process-

es need to be put in place, so that they do not become a limitation for further rounds of financing or an exit. It is also important for the investor to offer a reliable network and foster intensive dialogue with relevant figures in industry. This not only leads to easier access to additional investors for subsequent rounds of financing, but also to a lower hurdle to relevant partners who will play a key role as process or market experts, or even customers. Providing active support to the start-up team is the only way to ensure that the chances of the investment being a success are high.

6 Benefits of fund investments for corporations

By participating as investors in an investment fund and therefore being a limited partner (LP), established companies gain an insight into the innovation landscape and dynamics, while strict confidentiality is maintained. Through regular updates on subjects related to the deal flow, i.e. companies expressing interest and suggesting projects, as well as their involvement in the fund's decision-making process, companies gain a very broad overview of tech trends and future innovations. These pre-qualified start-ups can also become candidates for cooperation or an investment at a later

date – together with the experienced seed fund they have already invested in, if possible. The limited partners (LPs) therefore benefit from the experience that the fund has amassed through its investment activity.

Another benefit for the LPs lies in the fact that their field of view is almost automatically broadened by the cooperation with a seed fund that is investing in different industrial sectors. Even in areas that the LPs are not actively monitoring, they may come into contact with suitable technologies. Investing in a fund can therefore be a source of inspiration that cannot be tapped through an active strategic approach. Especially in situations with an unusual market dynamic and extraordinary innovation pressures – such as through the digital revolution that the industrial sector is currently undergoing – access to supplementary technological areas can represent a key advantage.

In addition, seed investors ideally enable their LPs to regularly interact with one another. Even though LPs appear heterogeneous at first glance, participants from the chemical companies come into contact with like-minded people from other industries and can learn from each other during regular exchanges. The fact that they share the same interests leads to a level of homogeneity that fosters targeted networking and highly effective exchanges.

7 Conclusion

Especially in a field so close to a mature industry like the chemical sector, interaction between start-ups, investors and industry is of paramount importance. This is an area in which close interaction produces synergies. For start-up companies, they enjoy a more targeted start to life and have a better chance of becoming a successfully established company. The investor, meanwhile, has better odds of achieving a positive exit, while the established company can maintain or boost its competitive position by integrating innovative technology.

References

Festel, G., Rittershaus, P. (2014): Fostering technology transfer in industrial biotechnology by academic spin-offs, *Journal of Commercial Biotechnology*, **20** (2), pp. 5-10.

Research Paper

From customer understanding to product understanding: Collaboration with industrial lead users in a B2B context

Magnus Tottie*, Thomas Lager** and Sofia Nordqvist***

* LKAB, 98381 Malmberget, Sweden

** EMINES – School of Industrial Management, Université Mohammed VI Polytechnique, 43150 Ben Guerir, Morocco, thomas.lager@emines.um6p.ma

*** Luleå University of Technology, 97187 Luleå, Sweden

Product innovation will continue to play a strategic role for companies producing high-quality, functional products for customers in the process industries. In the future, creating improved or radically new products will necessitate not only the development of product concepts resting more on an applied research knowledge base but also collaboration with customers. LKAB is a world-leading producer of processed iron ore products for steelmaking. The development of next-generation pellet products in collaboration with lead users presented an opportunity for a single case study in a B2B context. Two customers for present products as well as a technology/equipment supplier were identified as lead users. Using a framework grounded in lead user development, the Quality Function Deployment methodology (adapted to process-industrial use) was used as the facilitating instrument. It is concluded that this modified system will constitute an improved integrated knowledge-based platform for the development of new product and process concepts. It is argued that this development approach could also be applied in other process-industrial sectors serving industrial customers in an open innovation perspective.

1 Introduction

The process industries span several manufacturing industrial sectors (e.g. minerals & metals, pulp & paper, food & beverages, chemicals & petrochemicals, utilities and pharmaceuticals) and thus constitute a substantial part of all manufacturing industry. A key difference between companies in the process industries and those in other manufacturing industries is the former's often long, complex and rigid supply/value chains (Tottie and Lager, 1995). Moreover, the context for innovation differs radically; in the process industries, development takes place in laboratories and pilot plants rather than in a design office, and the final quality of products is often strongly related to available raw material properties. As a result, there is an intimate relationship between product and process innovation, summarized in the idea that "the process is the product" (Rousselle, 2012).

In the future, creating improved or radically new

products will necessitate not only an efficient product development work process but also the adaptation of development tools like the Quality Function Deployment methodology (QFD) for process industrial use. The Stage-Gate work process advocated by Cooper (1988b) must today be regarded as a de-facto standard for a formal product development process. The "fuzzy front end" of this process was introduced by Smith and Reinertsen (1991) as the first stages of the product development process, covering the period from ideation to approval to enter the product development stage. In 1988, Cooper found that the greatest differences between winners and losers were found in the quality of such pre-development activities (Cooper, 1988a). One important outcome of the fuzzy front end is a product concept that is usually restricted to a description of the new product idea and associated product specification. In a multiple case study in the area of front-end innovation of non-assembled product development, Frishammar et al. (2012)

recognized that, in the earliest phase of front-end activities, the identification of a “process window” in existing production process technology was also a common practice in which new product ideas were positioned.

The importance of using external information in development has been stressed in a vast number of publications (e.g. Chesbrough and Appleyard, 2007; Chesbrough, 2007) and is generally accepted today. In the process industries, such collaborative behavior is nothing new (Aylen, 2010). Thus, Trott and Hartman (2009) describe those open innovation activities as “old wine in new bottles”. Nowadays, even the most capable R&D organization needs to identify, connect to and leverage external knowledge sources as a core process in innovation. Resources from a company’s “relational capital” have thus been shown to be important in all stages of the product development process, from the problem recognition and idea generation, through product concept development, to prototyping and testing (Fuller et al., 2011). One approach in customer collaborations and co-development is to integrate lead users into the product development process (von Hippel, 1986). Luthje and Herstatt (2004) initially notice that lead users by definition do not just face any new need but rather recognize needs that most customers in the market will face in the future. Martinez (2014) identifies a need to incorporate the “Voice of the Consumer” at the center of the innovation process as well as a need for the ability to translate subjective consumer needs into objective product specifications.

Product innovation will continue to play a strategic role for companies in the process industries producing high-quality functional products for B2B customers. One such company, LKAB, is a world-leading producer of processed iron ore products for steelmaking. In their development of next-generation pellet products, they selected the QFD methodology as an overall framework and development tool to translate customer requirements into design requirements. The collaboration with lead users in this project presented an interesting opportunity for a single case study of the usability of the methodology in co-development with lead users and in a B2B context. The two research questions (RQ) to be answered in this study are as follows:

- RQ1: What is the general usability of the QFD methodology as a facilitating instrument in the co-development of products with lead users in a B2B context?
- RQ2: What is the specific usability of the multi-

ple progression QFD (mpQFD) system as an overall framework and knowledge-building tool in the pre-development part of product development in process industries?

The paper is organized as follows. First, the lead user development concept for co-development in a B2B context is reviewed and the QFD methodology is introduced. Afterwards, the research approach and the case company are presented. Next, the empirical evidence is presented, focusing on the use of the methodology as a facilitating tool. Finally, the results are discussed in the perspective of generalizing the research results to other sectors of the process industry and concluding with management implications and a research outlook.

2 A frame of reference: lead user collaboration in the B2B context and an introduction to the QFD methodology

2.1 The product development work process

The Stage-Gate system, also known as the Idea-to-Launch process, advocated and advertised by Cooper, must today be regarded as a de-facto standard for a formal product development work process. In his review of the system, Cooper (2009 and 2012) emphasizes the importance of gathering the Voice of the Customer and the importance of the fuzzy front end of the system. The Stage-Gate system was recently studied in a large sample of users and it proved to be an instrument that top-performing companies use often and well (Cooper, 2012). The product development process model in figure 1 is an example of a slightly modified Stage-Gate model that is adapted to a process-industrial context to be used as a template for this study.

The fuzzy front end of product development is the first stage of the new product development process, covering the period from ideation to approval to entering the next stage of product development (the fuzzy front end is designated as pre-development in figure 1). Reid and de Brentani (2004) also show that there is a clear distinction between early and late activities in this part; specifically, early activities are broad, while later activities consist of information collection and concept development (Backman et al., 2007). Product concepts are usually restricted to a description of the new product idea and related product specifications. In a similar vein, a process concept could also be defined (Kurkkio et al., 2011). Backman et al. (2007) advocate that the transition of concepts other than technology concepts also necessitates a contextualization in which the concept is dressed in such a

way as to fit a new product development context. In a study by Herstatt et al. (2004), Japanese front-end activities are compared with those of German companies, and it is proposed that Japanese companies rely on more formal approaches to reduce uncertainties during the pre-development part than German companies do. In a follow-up study, Herstatt et al. (2006) conclude that, in addition to knowing customer requirements, the gathered information has to be translated into technical specifications and integrated into the product concept. Verworn et al. (2008) note that *“there seems to be a lack of communication between marketing and technical functions and the customer requirements were not translated into technical language”*; an interesting conclusion that could favor the use of development methodologies such as QFD. In their study on the fuzzy front end as well as on discontinuous innovation improvements, de Brentani and Reid (2012) recommend that management also should provide a decision support system for codifying tacit knowledge, an attribute of the QFD system that so far has still not been properly recognized.

2.2 Co-development in the pre-development part of the product development work process

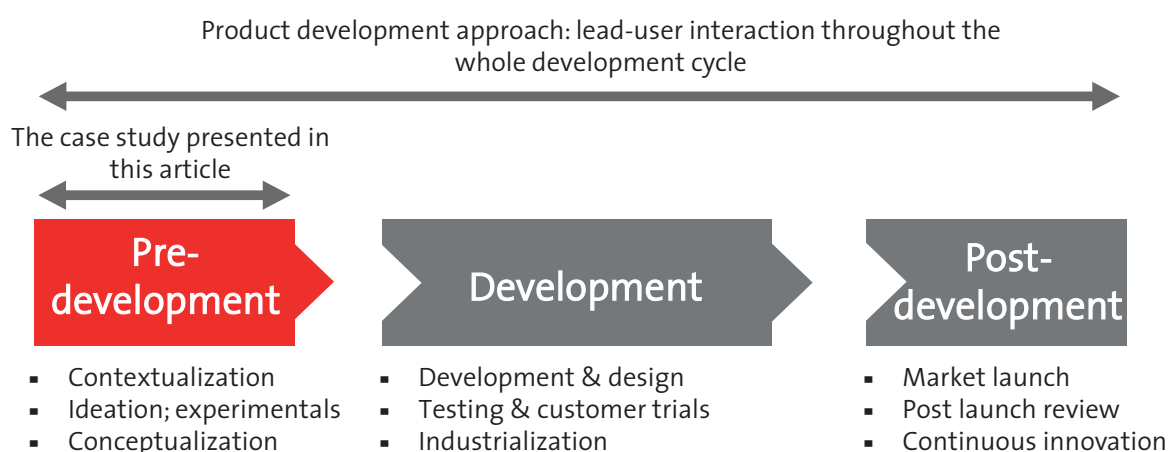
Toward the end of the eighties, von Hippel (1986) introduced the new development concept of integrating users of company products, processes and services into the innovation work process as “lead users”. In the discussion of lead users, it is impor-

tant to note that they can be individuals, groups or companies that have product needs beyond what is currently available in the general market (Eisenberg, 2011). The idea was grounded in the assumption that consumers, but also industrial customers, often have a limited insight into new product needs and potential solutions since they are constrained by their own real-world experiences. The concept of lead users proposes that this category of product (or process) users are in a better position to provide accurate data on needs related to future conditions. Additionally, the greater benefit a user can obtain from a novel product, the greater his effort to obtain a solution. In this study, we use a slightly modified definition of the lead user concept:

“Lead users are defined as members of a user population who (1) anticipate obtaining relatively high benefits from obtaining a solution to their needs and so may innovate and (2) are at the leading edge of important trends in the marketplace under study and so are currently experiencing need that will later be experienced by many users in the marketplace.” (Franke et al., 2006; von Hippel, 1986)

In the identification of lead users, and apart from being a trend leader, it is important that the lead user perceives a mismatch between his needs and the functions or performance of existing products (Luthje and Herstatt, 2004). Both components in this definition later proved to be independent dimensions (Franke et al., 2006). Luthje and Herstatt (2004) initially note that lead users by defi-

Figure 1 The product development work process with regard to integrating lead users. In this study, only the pre-development part of the work process, also known as the fuzzy front-end of product development, is studied.



dition do not just face any new need, but they realize needs that most customers in the market will face in the future. They also point out that lead users frequently play an important role in the development of new products particularly for industrial markets.

The lead user concept is similar to the concepts of co-creation and co-development that are also often used today. Bettencourt et al. (2014) challenge existing marketing practice and express value being created with customers in the context of use. A study by Macdonald et al. (2011) suggests that, in a B2B context, multiple respondents are needed in order to assess value-in-use at the individual as well as the organizational level. In a further discussion of B2B marketing and companies' interactions with other companies, Vargo and Lusch (2011) suggest that this knowledge base should also be used in general B2C marketing. In the active integration of innovative users in the innovation process, chemical and pharmaceutical companies such as BASF and Eli Lilly have successfully used open-source problem solving (Lakhani and Jeppesen, 2007). The findings of Fuller et al. (2011) show that it is the perceived autonomous, enjoyable experience that enables them to come up with superior solutions. The drivers for consumers to engage in co-creation are further studied by Fuller (2010), whereby the results are equally indicating that monetary incentives are not as important as the interactive experience itself.

2.3 An introduction to Quality Function Deployment and the mpQFD system

At the beginning of the seventies, Japan was the birthplace of a new methodology and tool for structuring customer requirements and translating them into design requirements as a new platform for product development (Akao, 2003). The first system, developed by Akao (Akao, 1990; Mizuno and Akao, 1994), is still the dominant system used in Japan. This system's breakthrough occurred in the Japanese manufacturing industry and is often ascribed to Toyota Auto Body, whose use of QFD successfully contributed to solving their problems with low-quality, rusting cars. The system's introduction in the European industry followed during the early nineties, and the first Swedish and European QFD projects in the process industries were reported in the mid-nineties (Tottie and Lager, 1995).

The most commonly used QFD system in other manufacturing industries is often called "the four phases of matrices" (Hauser and Clausing, 1988). Starting with the development of the House of Quality, the customer requirements' WHATs are translated into design requirements' HOWs, which

can then serve as WHATs in a consecutive matrix to express the demands on part characteristics and can afterwards be further progressed to the process planning and production planning matrices. This four-stage progression system is, however, not applicable to the process industries as the products of the latter are not assembled components. Additionally, the products and related production processes are firmly interlocked in the process industries, so that product and process innovation must always go hand in hand. Consequently, customer requirements on the product must not only first be translated into design requirements but also, and more importantly, must then be further progressed into the production system as requirements on process capabilities and on raw-material properties. The multiple progression QFD system (mpQFD) used in this project is thus specifically designed to fit process industrial needs (Lager 2005b). The system is illustrated in figure 2.

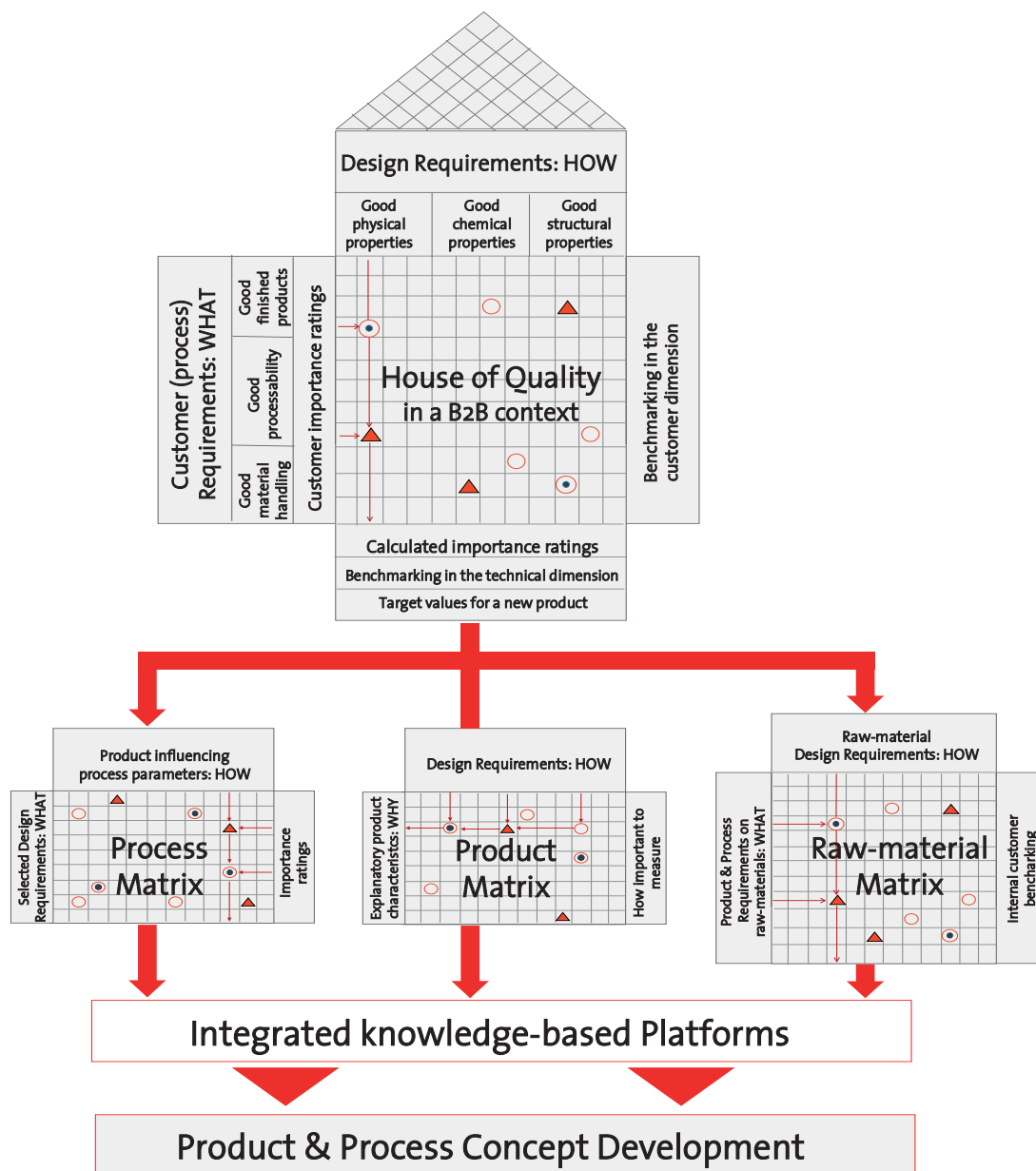
2.4 The House of Quality

In product development, when customer requirements are to be translated into design requirements, each requirement in one of these dimensions often relates to multiple requirements in the other dimension. This problem was solved with the basic QFD methodological matrix approach of positioning the design requirements at a right angle to the customer requirements and thereby defining a relationship matrix in which every possible relationship could be identified and assessed (Day, 1993). Because of its house-like shape, the matrix was later denominated as the "House of Quality" (figure 2). The importance ratings of the hierarchically arranged customer requirements, including a comparison with competing products in the customer dimension (customer benchmarking), are usually collectively called the "Voice of the Customer". When the relationship matrix is used to translate the Voice of the Customer into a technical dimension, those measurable design requirements are further developed, including the direction in which individual product properties need to be improved, as well as a calculation of the individual importance of each design requirement. In the technical dimension, there is now an opportunity to run a technical benchmarking of product properties. After completion of these "rooms", target values for a new or improved product can be set after a matrix analysis.

2.5 The product matrix

In the product matrix presented in figure 3, selected design requirements' HOWs from the

Figure 2 The multiple progression QFD system (mpQFD) adapted to process-industrial use is illustrated. Double rings symbolize a strong relation, single rings a medium-strength relation and triangles a weak relation between different requirement dimensions.



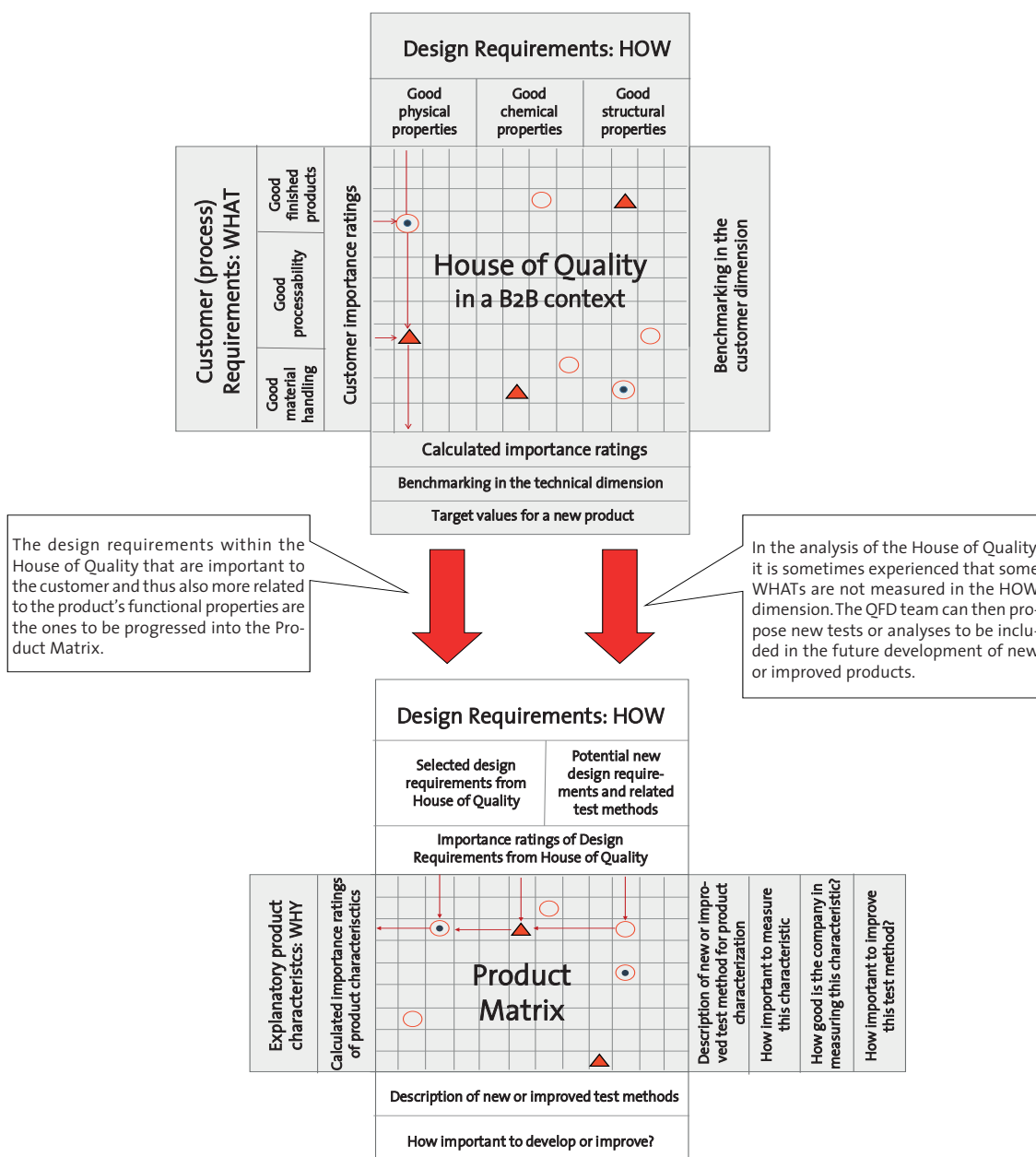
House of Quality are supplemented with new potential design requirements that are further related to inherent product characteristics' WHYS. This matrix, which contains explanatory product characteristics that will answer the question of how product functional properties are created, is "owned" by the R&D organization and will contain both

internal and external input, often of an applied research character. When the design requirements in the previously presented House of Quality are reviewed and if there is a need to develop new or more sophisticated measurement methods and techniques for company internal product development guidance, those complementary HOWs should

be included in this matrix. The complementary matrix is utilized either when a completely new product is being developed or if one is seeking an improved understanding of what kinds of deeper underlying mechanisms create the measurable properties of a product. The measurable properties of the final products, and to some extent the necessary process conditions that produce these prop-

erties, are often well known by company R&D. However, which inherent product characteristics create those properties, often difficult to measure and sometimes hard to understand, is generally less well known. The more internally and structurally heterogeneous a product is, the greater is the need for this complementary product matrix as a support in the development of new product concepts.

Figure 3 The House of Quality and the product matrix as well as their relation is depicted. Double rings symbolize a strong relation, single rings a medium-strength relation and triangles a weak relation between different requirement dimensions (Lager 2005b). The number of design requirements that can be progressed into the product matrix is limited in order to keep the size of the matrix to a minimum (left bubble). It is often discovered in QFD exercises that metrics for measuring customer requirements are lacking (right bubble).



3 Research approach

3.1 Action research and case study design

Action research can be undertaken by larger organizations or institutions assisted or guided by professional researchers, with the aim of improving their strategies, practices and knowledge of the environment in which they practice. The concept of “action research” was introduced by Lewin (1946) and further promoted by Argyris (2002) as the approach of active involvement combined with expected insights developed through research. Lewin stated that: “If social scientists truly want to understand certain phenomena, they should try to change them. Creating, not predicting, is the most robust test of validity-actionability”. A related concept termed “innovation action research”, proposed by Kaplan (1998), includes the following phases: observe and document innovative practice; teach, speak, and write articles; and implement the concept in new organizations. A similar concept was later suggested by Birkinshaw et al. (2008). This study project follows an innovation action research approach, involving all authors during seminars and discussions with lead users. The analysis and summary of the project outcomes related to the use of the QFD methodology at the case company LKAB, and finally the publication of this article, must also be considered well in the spirit of Kaplan’s proposed innovation action research implementation.

The development of LKAB’s next-generation pellet product in collaboration with three lead users (two customers and one equipment supplier to the customers), presented an interesting opportunity for a single case study of co-development in a B2B context. The team of researchers in this study included the three authors of this article with extensive industrial experience in the process industries, inputting first-hand knowledge not only of innovation management but also expertise in using the QFD methodology. There are naturally some disadvantages of doing case studies with prior understanding, but the advantages within a study of this kind can on the other hand be many and they have been well expressed by Markus (1977): “The problem is how to get beyond the superficial or the merely salient, becoming empirically literate. You can understand little more than your own evolving mental map allows. A naive, indifferent mental map will translate into global, superficial data and interpretations – and usually into self-induced bias as well. You have to be knowledgeable to collect good information.”

An important aspect of case studies is that they often provide rich contextual information that helps the reader to better understand where, when and

how the empirical evidence is valid. Since it was not necessary to anonymize the LKAB company, this study fulfilled this ambition well. Moreover, Yin (1994) outlines two requirements for conducting single case studies. A single case should be:

- *A unique case*: Collaboration with suppliers and customers is not unusual in the process industries, however, using customers and equipment suppliers to the customers as lead users in co-development in the process industries has not been reported on previously.
- *A revelatory case that offers a rare opportunity to observe a phenomenon that is normally inaccessible*: The opportunity to obtain first-hand information from the collaboration between a process company and its customers and an equipment supplier in an open atmosphere was a rare opportunity.

3.2 The case company and the development project

LKAB is a high-tech international minerals group, a world-leading producer of processed iron ore products for steelmaking and a growing supplier of mineral products for other industrial sectors. The company operates six pelletizing plants and in 2014, the company had a turnover close to EUR 2.2 bn. At several production sites in 2014, with around 4,000 employees in the northern part of Sweden, about 26 million tons of products were produced and delivered to LKAB’s customers. Pellets for blast furnaces and direct reduction plants account for the major part of the product mix. As a leading pellet innovator, the company has access not only to a recently started high-tech agglomeration laboratory but also to a unique experimental blast furnace (a customer process technology). Application development with its customers is a major concern for the company and “performance in iron-making” is its promise, which means that LKAB products should provide the best value for customers’ processes. To achieve this, it is important to have a continuous dialog with all customers regarding the performance and quality of the pellets. However, to stay ahead of the competition, it is also necessary to understand how future changes in processes, markets and competitors will influence the customer requirements of the product. Starting with the mining of iron ore, the process chain to produce steel products consists of several complex production stages. After mining, concentration and pelletizing, the finished product is transported by train to a harbor. At the point of loading the product onto the ships, the product changes ownership from LKAB to the customer.

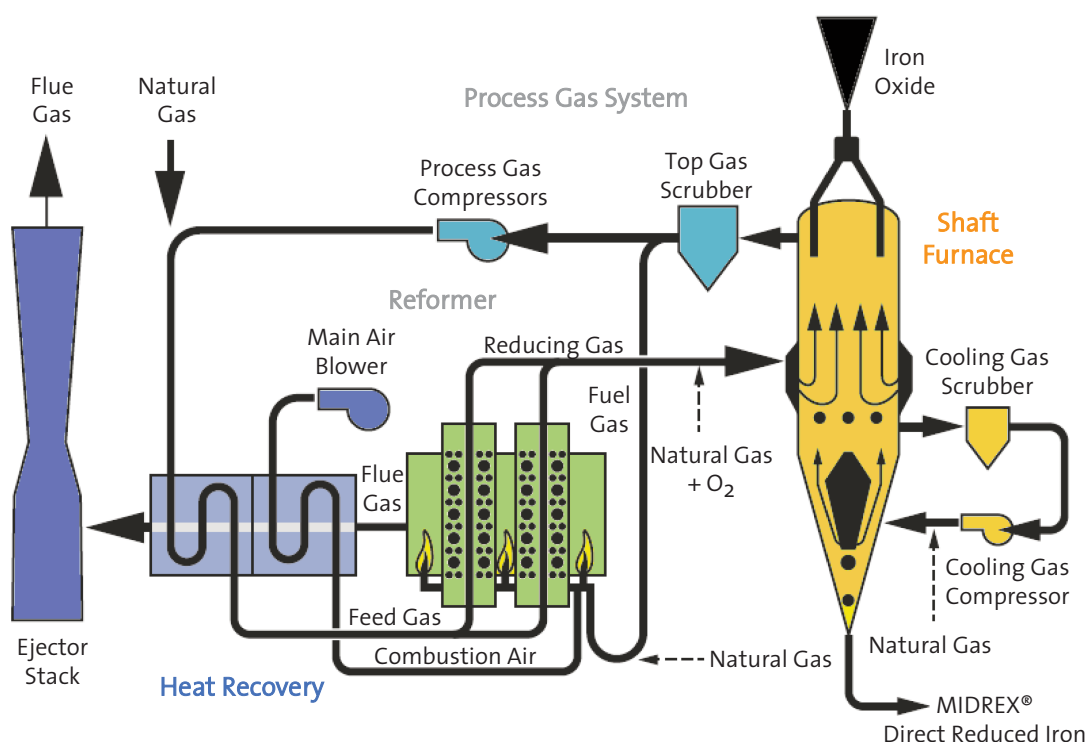
Customers using direct reduction technology are in focus for this product development project. Customers usually produce a rolled product such as rebar, wire rod, sections or coil. The first and most energy-intensive step is the reduction of iron oxide to direct reduced iron (DRI), or sponge iron, as it was originally called. Natural gas is reformed to a mix of CO and H₂ which reacts with oxygen in the iron ore at a temperature of up to 1,000 °C (figure 4). Key factors for the iron ore fed into this process are a high reductive potential, good strength and low tendency for clustering.

Unlike the product from the blast furnace reduction process, this product is solid. Thus, it needs to be melted in the steelmaking process. The steel-making process uses an electric arc furnace, the DRI is processed to steel with electricity as the main energy source. The liquid steel is further processed in a ladle furnace or vacuum degasser to produce the finished steel composition. The steel is then solidified in a continuous caster to produce billets

or slabs. Billets and slabs are afterwards rolled to what is usually the end product at the customer's company, which is distributed to manufacturers of intermediates and further products. In the development of iron ore pellets, it is thus important to consider the entire process chain to the end user.

The aim of the project studied here is to develop a "new generation of pellets" for the direct reduction process. The first step is to build a platform and understand customers' current and future needs. This information, along with new ideas for an improved pellet, will then guide further experimental work. After decades of metallurgical research, LKAB has a large portfolio of possible alternatives for modifying the properties of pellets. However, due to the poor ability of existing test methods to simulate the customer's full-scale process conditions, it is necessary to start with small-scale exploratory laboratory tests, following large-scale laboratory tests, pilot-scale tests and finally full-scale tests at a customer's premises. Compared to

Figure 4 Illustration of the MIDREX® direct reduction production technology. In order to understand the Voice of the Customer in a B2B situation, one must understand the customer's production technology and the demands the process puts on the product (Source: MIDREX®).



companies producing consumer products, LKAB has a limited number of industrial B2B customers, but the process of collecting data for the Voice of the Customer is crucial for the development of the products. However, it is important to select customers that have an interest in the development of both the supplied product and the development of their own production processes and are willing to spend time in co-development. The lead users should therefore ideally be those that will also be involved in the stages of the development of the product and finally as customers for the product. The steel plants usually have few own development resources, so that the best available knowledge of the process and of its future requirements can be found at their technology/equipment supplier. By means of user seminars and regular contact with the clients, such a technology supplier to LKABs customers is able to acquire an excellent base of knowledge not only of the production process but also of the raw materials used in this process.

4 Empirical findings

4.1 Listening to the Voice of the Customer

A development project using the QFD methodology usually starts with listening to the Voice of the Customer by carrying out a number of customer interviews in order to develop a hierarchic structure of individual customer requirements in iterative discussions with the customers. However, previous experiences with using the methodology in the process industries (Lager and Kjell, 2007), as well as the long geographical distance between the customers and LKAB, incentivized the development team to apply a more “lean” approach in drafting the Voice of the Customer. Using LKAB’s previous knowledge of customer requirements as a point of departure, those demands were further reviewed with in-house company marketing and R&D expertise in an iterative dialog, gradually refining them into a list of potential customer requirements before the first meetings with the customers. In discussions with the R&D and the marketing function (technical customer support), two lead users were selected and contacted by marketing. Since the customer for a product in a B2B context is the production process through which a supplied product will be processed, it was important that representatives working close to the production process would be present during discussions.

In the first meeting with each lead user, the development project was initially introduced. Afterwards, the QFD methodology was presented and informational material about the methodology

was distributed. It was stressed that the intention was initially to focus on the development of the “core product” but that LKAB would later return to the subject of building the Voice of the Customer both on “improved logistics” and “improved application development and services” for the customers. Next, the structured list of customer requirements was presented and discussed in an open dialog, and each customer requirement was then discussed separately and challenged how easy it was to understand. After the interviews with the two customers, the draft list and structure of customer requirements was revised and discussed with the technology/equipment supplier. After the meetings, the revised draft list was sent out to the customers for further comments and improvements.

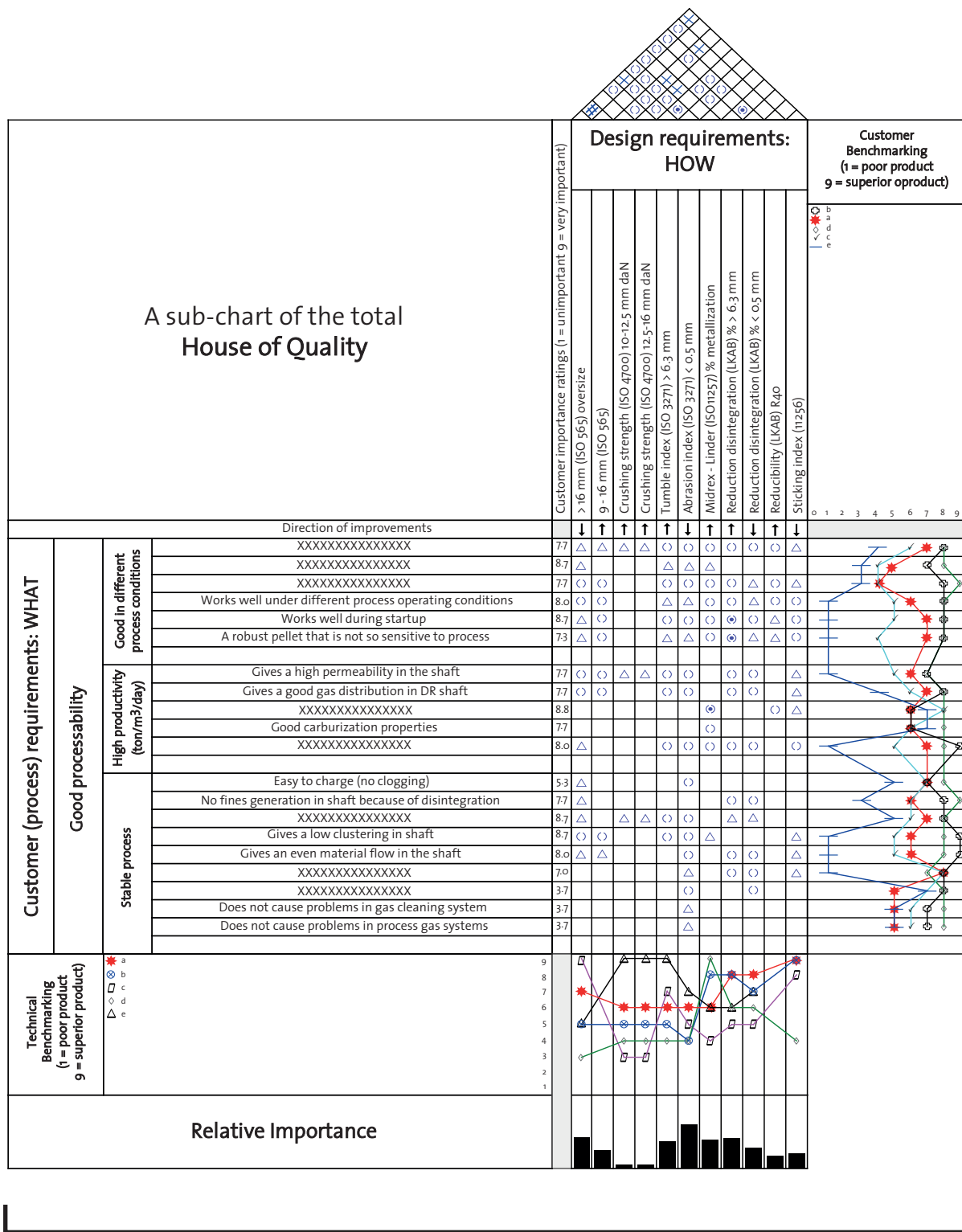
In a second round of meetings with the lead users, each customer was asked to rate the importance of each requirement on a nine-point ordinal scale (1=unimportant; 9= very important). After this rating, they were asked to benchmark LKAB’s product properties with competing products in the customer dimension on a nine-point ordinal scale (1=poor product; 9=world-class product). The technology/equipment supplier was asked to rank the three most important customer demands from the perspective of important needs for their future process development and new equipment (figure 5). All lead users were informed that after LKAB had built the House of Quality, they would be contacted for further discussions about individual parts of the relationship matrix. In order to facilitate such contacts, they were offered the necessary software for discussion (IDEACore, 2003).

4.2 Developing a House of Quality

The Voice of the Customer was translated into a technical dimension in the House of Quality (figure 5). This task, which was performed internally at LKAB, involved the company’s senior expertise in product development. An example of the dynamics of the matrices is as follows: the customer requirement “works well during startup” has no relation to the requirement “crushing strength” (of a pellet) but has a medium-strength relation to the design requirements “tumble index” and “abrasion index”. The technical data are the results from laboratory testing on LKAB products and on competitors’ products. The roof of the House of Quality is often called the correlation roof. Since products from the process industries are more or less homogenous, changing the intensity of one design requirement will often have a corresponding effect on another design requirement.

This is complicating product development in the process industries which makes the correlation

Figure 5 A selected part (sub-chart) of the House of Quality. In the room "direction for improvements" (IDEACore, 2003), an upward-pointing arrow represents a desire for improving a design requirement, while a downward-pointing arrow represents a desire to diminish the design requirement. Double rings symbolize a strong relation, single rings a medium-strength relation and triangles a weak relation between different requirement dimensions. In the roof, crosses symbolize design requirements that are hostile to each other, while rings represent design requirements that are friendly to each other. The censored parts (XXX) represent customer requirements that are confidential.



room rather important. This can also be seen in the roof of figure 5. Since the relation between the design requirements “tumble index” and “abrasion index” is strongly positive, an improvement of the “tumble index” will automatically show a decrease in the “abrasion index”, which is very positive since the disintegration of pellets is not wanted.

On the other hand, when the design requirement “>16mm” increases, the fraction between “9-16mm” decreases, which is strongly negative since that fraction is the preferred one. The relationship matrix was afterwards used to calculate the importance ratings in the technical dimension, using the importance ratings of the individual customer requirements. As we can see here, a well-designed House of Quality built on a solid ground of the Voice of the Customer is a tool for setting interactive product specifications for new products or improvements.

4.3 Developing the product matrix

In order to create the product matrix, brainstorming sessions regarding features creating the functionality in a pellet were held with LKAB’s experts on pelletizing and product development. These features were then classified and organized in a structured list, which is denominated as the WHYs in the matrix (figure 6). In the House of Quality, the measurements for the design requirements are mainly internationally recognized standard test methods and some of them are discussed with the customers. However, since these test methods sometimes do not correlate well with how well the product behaves in the customers’ processes, one objective with the product matrix was to examine potentially better test methods in order to develop an improved product. Thus, the product matrix is a tool not only for relating design requirements’ HOWs to exploratory product characteristics’ WHYs but also, and more importantly, for guiding the development of better test methods.

For example, from the House of Quality it can be seen that the customer requirement “works well during startup” has been given a weight of 8.7, so it is considered to be very important. It has also a medium-strength relation to the design requirement “abrasion index” as well as a strong relation to the design requirement “reduction disintegration (LKAB) % > 6.3” that is considered to be of great importance for the other customer requirements due to its high relative importance. These design requirements are progressed into the product matrix, where they are strongly related to, for instance, the explanatory product characteristic “bindings between particles”, implying that such bindings are needed to be controlled in order to

create pellets with the design requirements low “abrasion index” and high “reduction disintegration (LKAB) % > 6.3” and hence, to be in line with the customer requirement, “works well during start-up”.

4.4 Some general experiences and future activities

Since only two customers and one supplier were selected as lead users, the validated Voice of the Customer will be used in future contacts with all customers, preferably in connection with normal contact meetings but likely in some cases also as a mailed survey. The House of Quality will be further used during the following development phase in interaction and discussions with customers. These will not be discussions of the full House of Quality but rather of cut-out pieces (sub-charts) of the matrix selected in order to develop a greater consensus on how the design requirements relate to customer (process) requirements. One shortcoming in co-development with lead users selected from a company’s existing customers and users of the company’s existing products is that they often, and rightly, focus on existing production processes, today’s product properties, and their related advantages and disadvantages of these. For this reason, one equipment supplier was selected and accepted for involvement as a lead user.

The development of the product matrix proved to be a long and iterative journey of learning. Since the product characteristics’ WHYs had never been collected and systematically structured, the development of this part of the matrix took considerable time and effort by the R&D organization. During consecutive meetings, different internal experts and specialists became engaged, and this continued throughout the development of the relational matrix. The matrix proved to develop into a very interesting instrument for organizational learning and a collection of tacit LKAB knowledge that already existed (de Brentani and Reid, 2012; Polanyi, 1983) to some extent in the R&D organization. The product matrix will be further developed and will be in a constant state of flux during the whole development cycle. As one researcher pointed out, this matrix will provide a platform for the development of “conceptual explanatory models” that describe how product functionalities are related to more or less measurable product-inherent characteristics.

5 Discussion and managerial implications

The usability of the QFD methodology as a product development tool has been generally acknowledged (Griffin, 1992; Griffin and Hauser, 1993; Lager, 2005a; Miguel, 2013), not only as a solitary methodology but also as a part of other methodological approaches like TQM and Design for Six Sigma (Tenant, 2002). Returning to research question 1, the usability of the QFD methodology as a facilitating tool has only been studied in the pre-development stage of a product development project in this case study. As such, this methodology has proven to be a useful tool in the dialog with B2B customers. However, the development team is inclined to believe that the deployment of the methodology could be expanded further, and will actively pursue its use in the following development stage. It is thus presumed that QFD can also be further deployed in post-product development activities, including the marketing of future improved or new products.

Backman et al. (2007) show that the formal processes designed to deal with product concepts at the front end are insufficient, especially in terms of market and customer-driven concepts. In this study, it is argued that the formal work processes for product development at the front end are also not well adapted to delineate production-driven requirements. In the process industries, where the products are intimately connected to the production process (Frishammar et al., 2012; Lager et al., 2013; Rousselle, 2012), it is not sufficient to go from pre-development to product development based on a single product concept. In order to develop products that also are designed for “manufacturability” (Boothroyd et al., 1994), it is proposed that the product concept will need a complementary process concept. Such a process concept then defines what production capabilities are needed in order to manufacture the new product defined in the product concept. Depending on the newness (incremental/radical character) of necessary production capabilities, the process concept may only include minor process adjustments or reconfigurations. However, for radically new products, it may sometimes include new production technology requiring substantial capital investments. The conceptualization phase of product development in the process industries should thus involve the development of both a product concept and its related process concept. Such complementary concepts should be well integrated and their conceptualization is likely to be a highly iterative process.

Referring to the multiple progression system presented in figure 2, such new process concepts will probably benefit from the associated development of process and raw material matrices as an

“integrated knowledge platform” for further conceptualization. After the completion of the House of Quality and the product matrix, it was thus evident to all project members that one piece of information was still missing. The Voice of the Customer had been translated into design requirements and further progressed into the product matrix and related to inherent product characteristics, but the link to the production process was still lacking. Since the importance of using the process matrix and the raw-material matrix in the mpQFD system is stressed, a future step in this project will be to develop such matrices.

Returning to research question 2, the use of the system in the development of the product matrix proved to be an interesting route to follow. From a management perspective, the usage of these matrices and the creation of an integrated knowledge-based platform contributes to a continuous visualization of knowledge throughout the product and process development. This platform presents an important dynamic capability in order to generate competitive advantage as it reinforces and may even alter and improve the entire knowledge base of the company.

Different sectors of the process industry share a large number of characteristics related to their production systems and their innovation environment, but those characteristics significantly differ from other manufacturing industries. The consequence is that results from researching innovation in other manufacturing industries are of less interest to the process industries, while research aiming at the process-industrial cluster of industries are likely to be most interesting to, if not all, but for many sectors of the process industries. In one previous workshop related to innovation in a process-industrial context, it was thus concluded that: *“It is not to be said that prior research into management of R&D and innovation in general does not apply to the process industries, but rather that research results from other domains may very well be useful for the family of process industries as well. However, the idiosyncrasies of process firms are likely to influence the conduct of R&D and innovation and call for improved methods, tools and an actionable and improved knowledge base for R&D management and innovation.”* (Lager et al., 2013).

In this perspective, it is argued that the research results of using the Quality Function Deployment methodology adapted for process-industrial use (mpQFD) in this case study could be applied in many different sectors of the process industry. Since products e.g. from the chemical industry are often supplied in a B2B context to other process sectors like the minerals & metals, pulp & paper and food &

beverage industries, using industrial lead users should be an interesting avenue to follow.

6 Conclusions and further research

The usability of the QFD methodology for the co-development with lead users can be confirmed with regard to the iterative development of the Voice of the Customer. Discussions flowed well during the meetings in different cultural settings and the otherwise common discussions of a single product specification and “the problem of the day” were avoided. The outcomes from the discussions and the tangible information related to the customers’ use of the product in their production processes can be expressed as an improved customer understanding. The initial idea to engage a technology/equipment supplier to the customers as a lead user proved to be a sound development approach. Involving the customers’ technology/equipment supplier as a lead user in B2B product development, is thus one general recommendation and contribution of this study, which is in line with previous experiences (Aylen, 2010; Lager and Rennard, 2014). So far, the methodology has only been used in the pre-development part, but the lead users will afterwards also be involved in the development phase.

The overall impression of those involved in this project and the general conclusion of this study is that the QFD system has a strong potential to be deployed as an instrument for knowledge building in product and process development. Selected design requirements, supplemented with new measures, were progressed into a product matrix, where they were related to explanatory inherent product characteristics. This new matrix provided an applied research knowledge platform for improved “product understanding”. This is consistent with previous findings indicating that, in order to reap the fruits of this methodology, one must have a long-term perspective (Griffin, 1992; Lager, 2005a), contrary to the arguments advocating a fast “blitz QFD” approach. It was further discovered that this knowledge-building capability of the methodology was closely related to the functionality of the software and its ability to relate and save information to all matrix areas and rooms and even relate information to individual symbols in the matrices. The use of pop-ups displaying this information proved to be very valuable during the working sessions. Absorptive capacity refers to one of a firm’s fundamental learning processes – namely, its ability to identify, assimilate and exploit knowledge from the environment – and is crucial for long-term success, since it can reinforce, complement or refocus the knowledge base of a firm (Lane et

al., 2001). The systematic use of the matrices and the way the QFD methodology has been used in the pre-development phase – for gathering, valuing and analyzing new knowledge about customer requirements – is believed to contribute to the potential absorptive capacity of the case company. In addition, further usage of the method throughout the development and post-development phases will enhance the transformation and exploration of new knowledge, reinforcing the realized potential capacity (Zahra and George, 2002). Using the QFD methodology as a facilitating tool in the pre-development part of product development in a co-development approach with B2B lead users has proven to be an interesting and important avenue to follow. It is argued that such a development approach could also be used in product development in other process-industrial sectors serving industrial customers in an open innovation perspective.

The often cited disadvantage of the QFD methodology that it is a time- and resource-demanding tool proved to be correct. This was, however, not a serious problem in this project due to its long-term development perspective and the very large amount of other resources that are and will be used in the future, including pilot testing and full-scale trials. However, if the matrices are to be used only in a single event and in a “crash development project”, this could be a significant disadvantage. The further use of the QFD methodology in the LKAB project will be an interesting topic for a follow-up longitudinal study, and then in particular the use of the matrices for concept development. The development of well-integrated product and process concepts as a project deliverable before entering the development stage in the product development work process shows promise as an area for future exploration. Finally, the experience of using the QFD methodology not only as a facilitating instrument in contacts with customers but also as a way to enhance absorptive capacity through usage as a general knowledge-building tool and system in company product and process development is another area of interest for further studies.

Acknowledgments

The LKAB group’s support and permission to publish this article is much appreciated. The anonymized lead users’ participation in this project is also well recognized. Many thanks to Lars Norrman as a key operator in the project and a discussion partner. We gratefully acknowledge the suggestions for improvements on the article structure and content from referees.

References

- Akao, Y. (2003): The leading edge in QFD: past, present and future, *International Journal of Quality & Reliability Management*, **20** (1), pp. 20-35.
- Akao, Y. (1990): *Quality Function Deployment: Integrating Customer Requirements into Product Design*, Productivity Press, Cambridge.
- Argyris, C. (2002): Double-Loop Learning, Teaching, and Research, *Academy of Management Learning and Education*, **1** (2), pp. 206-218.
- Aylen, J. (2010): Open versus closed innovation: development of the wide strip mill for steel in the USA during the 1920's, *R&D Management*, **40** (1), pp. 67-80.
- Backman, M., Börjesson, S. and Setterberg, S. (2007): Working with concepts in the fuzzy front end: exploring the context for innovation for different type of concepts at Volvo Cars, *R&D Management*, **37** (1), pp. 17-28.
- Bettencourt, L.A., Lusch, R.F. and Vargo, S.L. (2014): A Service Lens on Value Creation: Marketing's Role in Achieving Strategic Advantage, *California Management Review*, **57** (1), pp. 44-66.
- Birkinshaw, J., Hamel, G. and Mol, M.J. (2008): Management Innovation, *Academy of Management Review*, **33** (4), pp. 825-845.
- Boothroyd, G., Dewhurst, P. and Knight, W. (1994): *Product Design for Manufacture and Assembly*, Marcel Dekker Inc, New York.
- Chesbrough, H. and Appleyard, M.M. (2007): Open Innovation and Strategy, *California Management Review*, **50** (1), pp. 57-76.
- Chesbrough, H.W. (2007): Why Companies Should Have Open Business Models, *MIT Sloan Management Review*, **48** (2), pp. 21-28.
- Cooper, R.G. (1988a): Predevelopment Activities Determine New Product Success, *Industrial Marketing Management*, **17**, pp. 237-247.
- Cooper, R.G. (1988b): *Winning at New Products*, Kogan Page, London.
- Cooper, R.G. (2009): How companies are reinventing their idea-to-launch methodologies, *Research-Technology Management*, **52** (2), pp. 47-57.
- Cooper, R.G. and Edgett, S.J. (2012): Best Practices in the Idea-to-Launch Process and Its Governance, *Research-Technology Management*, **55** (2), pp. 43-54.
- Day, R.G. (1993): *Quality Function Deployment - Linking a Company with Its Customers*, ASQ Quality Press, Milwaukee.
- de Brentani, U. and Reid, S.E. (2012): The Fuzzy Front-End of Discontinuous Innovation: Insights for Research Management, *Journal of Product Innovation Management*, **29** (1), pp. 70-84.
- Eisenberg, I. (2011). Lead user research for breakthrough innovation, *Research-Technology Management*, **54** (1), pp. 50-58.
- Franke, N., von Hippel, E. and Schreier, M. (2006): Finding Commercially Attractive User Innovations: A Test of Lead user Theory, *Journal of Product Innovation Management*, **23**, pp. 301-315.
- Frishammar, J., Lichtenthaler, U. and Kurkkio, M. (2012): The front end in non-assembled product development: a multiple case study of mineral- and metal firms, *Journal of Engineering and Technology Management*, **29**, pp. 468-488.
- Fuller, J. (2010): Refining Virtual Co-Creation from a Consumer Perspective, *California Management Review*, **52** (2), pp. 98-122.
- Fuller, J., Hutter, K. and Faullant, R. (2011): Why co-creation experience matters? Creative experience and its impact on the quantity and quality of creative contributions, *R&D Management*, **41** (3), pp. 259-273.
- Griffin, A. (1992): Evaluating QFD's Use in US Firms as a Process, *Journal of Product Innovation Management*, **9** (3), pp. 171-187.
- Griffin, A. and Hauser, J.R. (1993): The Voice of the Customer, *Marketing Science*, **12** (1), pp. 1-27.
- Hauser, J. R. and Clausing, D. (1988): The House of Quality, *Harvard Business Review*, **66** (3), pp. 63-73.
- Herstatt, C. and Stockenström, C. (2006): "Fuzzy Front End" practices in innovating Japanese companies, *International Journal of Innovation and Technology Management*, **3** (1), pp. 43-60.
- Herstatt, C., Verworn, B. and Nagahira, A. (2004): Reducing project related uncertainty in the "fuzzy front end" of innovation, *International Journal of Product Development*, **1** (1), pp. 43-65.
- IDEACore (2003): QFD Designer 4.0, IDEACore, Birmingham.
- Kaplan, R.S. (1998): Innovation Action Research: Creating New Management Theory and Practice, *Journal of Management Accounting Research*, **10**, pp. 89-118.
- Kurkkio, M., Frishammar, J. and Lichtenthaler, U. (2011): Where process development begins: A multiple case study of front end activities in process firms, *Technovation*, **31**, pp. 490-504.
- Lager, T. (2005a): The industrial usability of quality function deployment: a literature review and synthesis on a meta-level, *R&D Management*, **35** (4), pp. 409-426.
- Lager, T. (2005b): Multiple Progression - A Proposed New System for the Application of Quality Function Deployment in Process Industry, *International Journal of Innovation Management*, **9** (3), pp. 311-341.
- Lager, T., Blanco, S. and Frishammar, J. (2013):

Managing R&D and Innovation in the process industries, *R&D Management*, **43** (3), pp. 189-195.

Lager, T. and Kjell, Å. (2007): *Multiple Progression QFD: A case study of cooking product functionality at Arla Foods*, Paper presented at 13th International & 19th North American Symposium on QFD, September 7-8, 2007, Williamsburg.

Lager, T. and Rennard, J.-P. (2014): Managing the manufacturing - R&D interface: an extended editorial viewpoint, *Journal of Manufacturing Technology Management*, **25** (2), pp. 146-154.

Lakhani, K.R. and Jeppesen, L.B. (2007): Getting Unusual Suspects to Solve R&D Puzzles, *Harvard Business Review*, **85** (5), pp. 30-32.

Lane, P., Salk, J.E. and Lyles, M.A. (2001): Absorptive Capacity, Learning and Performance in International Joint Ventures, *Strategic Management Journal*, **22** (12), pp. 1139-1161.

Lewin, K. (1946): Action research and minority problems, *Journal of Social Issues*, **2** (4), pp. 34-46.

Luthje, C. and Herstatt, C. (2004): The Lead User method: an outline of empirical findings and issues for future research, *R&D Management*, **34** (5), pp. 553-568.

Macdonald, E.K., Wilson, H., Martinez, V. and Toosi, A. (2011): Assessing value-in-use: A conceptual framework and exploratory study, *Industrial Marketing Management*, **40** (5), pp. 671-682.

Markus, H. (1977): Self-Schemata and processing information about the self, *Journal of Personality and Social Psychology*, **35** (2), pp. 63-78.

Martinez, M.G. (2014): Co-creation of Value by Open Innovation: Unlocking New Sources of Competitive Advantage, *Agribusiness*, **30** (2), pp. 132-147.

Miguel, P.A.C. (2013): Benchmarking QFD application for developing packaging products: a comparison between a company in Italy and one in Brazil, *Benchmarking: An International Journal*, **20** (3), pp. 419-433.

Mizuno, S. and Akao, Y. (1994): *QFD: The Customer-Driven Approach to Quality Planning and Deployment*, Asian Productivity Organization, Tokyo.

Polanyi, M. (1983): *The Tacit Dimension*, Peter Smith Publisher, Gloucester.

Reid, S.E. and de Brentani, U. (2004): The Fuzzy Front End of New Product Development for Discontinuous Innovations: A Theoretical Model, *Journal of Product Innovation Management*, **21** (3), pp. 170-184.

Rousselle, T. (2012): R&D Management conference, Grenoble: Ecole de Management.

Smith, P.G. and Reinertsen, D.G. (1991): *Developing products in Half the Time*, Van Nostrand Reinhold, New York.

Tennant, G. (2002): *Design for Six Sigma*, Gower Publishing Ltd., Aldershot.

Tottie, M. and Lager, T. (1995): QFD-Linking the

Customer to the Product Development Process as a Part of the TQM Concept, *R&D Management*, **25** (3), pp. 257-267.

Trott, P. and Hartman, D. (2009): Why "open innovation" is old wine in new bottles, *International Journal of Innovation Management*, **13** (4), pp. 715-736.

Vargo, S.L. and Lush, R.F. (2011): It's all B2B ... and beyond: Toward a systems perspective of the market, *Industrial Marketing Management*, **40** (2), pp. 181-187.

Verworn, B., Herstatt, C. and Nagahira, A. (2008): The fuzzy front end of Japanese new product development projects: impact on success and differences between incremental and radical projects, *R&D Management*, **38** (1), pp. 1-19.

von Hippel, E. (1986): Lead Users: A source of Novel Product Concepts, *Management Science*, **32** (7), pp. 791-805.

Yin, R.K. (1994): *Case Study Research: Design and Methods*, Vol. 5, Sage Publications, Thousand Oaks.

Zahra, S.A. and George, G. (2002): Absorptive capacity: A review, reconceptualization, and extension, *Academy of Management Review*, **27** (2), pp. 185-203.

Practitioner's Section

The logistics profile of the German chemical industry

Martin Schwemmer* and Annemarie Kübler*

* Fraunhofer Center for Applied Research on Supply Chain Services (SCS), Nordostpark 93, 90411 Nürnberg, martin.schwemmer@scs.fraunhofer.de

The article aims at giving basic data and interpretations on the chemical logistics sector in Germany. The findings are based on a combination of primary research and secondary data in the field of logistics service providers, logistics agglomerations and logistics employment. Logistics service providers that are specialized in services for the chemical industry are identified. The special requirements for logistics handling goods for the chemical industry are derived and logistics clusters in the German chemical industry are presented. The development of logistics employment indicates that logistics activities in the chemical sector are frequently outsourced.

1 Introduction

Global players such as BASF, Henkel or Dow Chemical are competitors within the chemical industry which is an important business sector. Interconnections between the industry and other sectors such as the automotive manufacturing industry, the pharmaceutical or the consumer goods production industry underline this importance.

The chemical sector has a unique supply chain and demands a range of logistics services. Make or buy decisions regarding logistics projects are frequently required. As deciders and supply chain operators often need to plan under high uncertainty (Chae, 2009), basic data regarding the structure of the sector's logistics set-up on particular geographical markets is essential in order to support decision-making processes.

Contemporary logistics research tends to be focused on particular topics and case studies focus on single companies or particular developments. Apart from that, the purpose of this essay is to deliver approaches and basic quantitative data on the chemical industry and its logistics environment over time. The research work presented in this article is based on evaluations and ongoing work of the Fraunhofer Center for applied research on Supply Chain Services (SCS) for the purpose of building knowledge, expertise and data on supply chain services. Basic studies of Fraunhofer are addressing logistics market sizes, market segments, logistic service providers (LSPs), logistics employment, logistics locations, trade interconnections and future

trends. The basic motivation is to improve circumstances for complex decision situations that occur on a daily basis in globally interconnected firms, their supply chains and, following Cooper et al. (1997), supply networks. Referring to Cooper et al. (1997), a supply chain seldom looks like a pipeline, but more like a tree with its roots and branches, which need to be managed properly.

The structure of this article is as follows. Subsequent to the introduction, section 2 gives an overview of the chemical industry in Germany. Sections 3 to 5 provide insights in methods and results for three different dimensions of the chemical industry's logistics: the chemical logistics market (section 3), the chemical logistics employment (section 4) and the chemical logistics sites in Germany (section 5). Each of these sections 3 to 5 presents methods as well as results. Section 6 shows trends that the chemical logistics industry is currently facing. Section 7 concludes with final remarks and suggests fields where research should help to gain transparency on industry-specific logistics.

2 The chemical industry in Germany

In 2013, the chemical and pharmaceutical industry reached total revenues of EUR 854 bn in Europe and held a share of more than 10% of the total European manufacturing industries' turnover (Eurostat, 2015; own calculations). For Germany, the corresponding figures show revenues of about EUR 147 bn (Destatis, 2015; own calculations). About 17% of the European total revenues of this industry are con-

centrated in Germany and about 328,000 employees work in the sector (Destatis, 2015; own calculations).

Figure 1 shows the products manufactured by the German chemical sector in the year 2013. About two thirds of the revenues are generated by manufacturing and selling basic chemicals. Soap and detergents (9%), coating and paints (7%) as well as chemical fibers (2%) and pesticides (1%) occupy further shares. A noticeable share of 14% of the manufactured products is clustered as other products in statistics, showing that the chemical industry holds a variety of products that cannot be clustered otherwise.

Dominating trading partners in im- and exports are the Netherlands, Belgium and France. Most of the neighboring European countries are customers of Germany's chemical sector. The flows of goods predominantly consist of basic chemicals presenting 82% of imports and 77% of exports (Kille and Schwemmer, 2014).

3 The market for chemical logistics

3.1 Methodological remarks and data processing

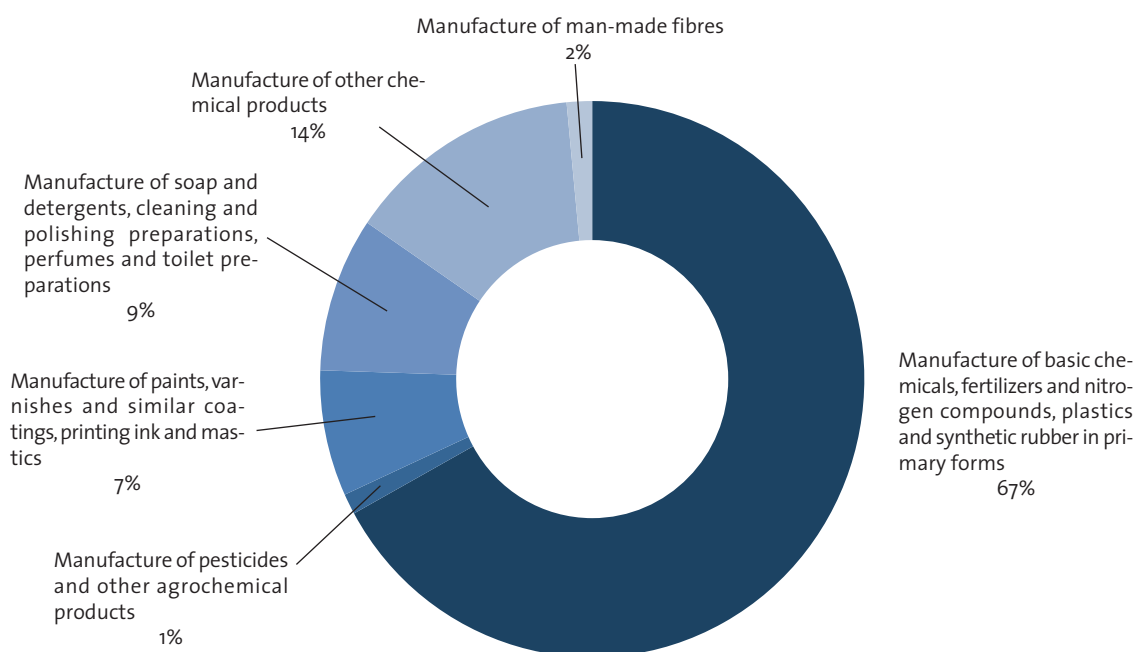
For the basic analysis of an industrial sector and the market for logistics activities for and in this sec-

tor, we first partition the field of interest into smaller sections that can be measured by using different approaches. A market is a physical or virtual space that connects supply and demand for products or services. Such a market can be segmented into its basic parts that are the suppliers and demanders. As they do not do business for an altruistic reason, the items of interest why suppliers and demanders work together also need to be taken into account, i.e. the goods (compare Bofinger, 2011).

3.1.1 Statistical classifications as key to ascertain facts on industrial sectors

One of the most important approaches to assess industrial sectors from an economic perspective is to use established industrial classification systems (such as ISIC, NACE in Europe or WZ08 in Germany). These systems provide distinct codes that enable a targeted analysis of parts of an economy and enable combining data from different statistical sources on revenues, tonnages moved, employees, the value of traded goods, type and number of relevant goods etc. in a sector. Furthermore, through the combination of these items of data, ratios can be calculated and compared across different sectors. In addition, the development of those figures can be traced via time series analyses. When using

Figure 1 Product portfolio of the chemical industry in Germany and associated shares of revenue (Kille and Schwemmer, 2014, p. 161; data from Destatis 2015).



data this way, a basic prerequisite is that the retrieved statistics are structured according to these industry classifications. If data is prepared by using different classification systems, extensive efforts are necessary to harmonize this data to enable a joint analysis.

The German statistical classification WZ 2008 was developed by the Federal Statistical Office of Germany (Statistisches Bundesamt, 2008) and is commonly used. It also forms the basis for the evaluations of this essay. As this classification is corresponding to NACE Rev. 2, comparative analyses with data available from Eurostat on different countries of Europe is possible.

3.1.2 Manufactured and traded goods characteristics

The basic requirements for logistics can be derived from the nature and type of the goods that are manufactured and traded within an industry. The WZ 2008 system differentiates 16 types of manufactured goods for the chemical manufacturing industry (wholesale and raw material mining are excluded) (Statistisches Bundesamt, 2008). This classification system defines which products are included and which are excluded for every type of goods. To align interpretations from statistical data, sighting and clustering the manufactured goods regarding their physical characteristics is useful. Some basic characteristics regarding the logistics needs of goods are fluidity, bulkiness, solidity, toxicity and fugacity, which decide about how goods are handled and transported, e.g. either as palletized or packed goods, or via tanker.

In general, the typical means of transport can be derived via literature research and can be adapted to individual cases. Special issues might require additional qualitative or quantitative primary research among practitioners from the respective industry.

3.1.3 Assessing the demand side in logistics markets

Demanders in industrial logistics markets are those that have goods in need for transportation services. The following approach is used in order to identify the most relevant demanders within a specific industry (as surveying practitioners often does not result in a comprehensive list).

In step 1, data is extracted from company databases. There are some of them available for the German market and even more for other countries. Usually, these databases allow an export of data according to the industrial classifications that are used by statistical offices. Combined with the infor-

mation on the turnovers of these firms that are mostly available in database extracts, a draft version of an industrial sector's top firm ranking may easily be achieved. However, pitfalls and shortcomings of such rankings often come to light. The most frequent reason for problematic results is that the assignment of firms to industry sector codes is not as distinct as desirable. In addition, the affiliation is sometimes inadequate as many firms are active in different fields through a diversified setup. Thus, one statistical code might not be sufficient to classify such firms. For example, this is the case for Siemens, a global player in machinery, electricity, plant construction and other sectors. Therefore, company databases also display one or more secondary classification codes as a method to resolve such shortcomings. Usually, a company description is also available to characterize companies. Nevertheless, these pieces of information are insufficient to obtain a valid list of top firms in an industry without considering further information.

To set up a ranking, additional research needs to be carried out that encompasses the screening of business profiles, business reports, magazines and similar sources. An exchange with experts is helpful if a list needs to be set up from scratch, i.e. if not a single source or company database can be drawn from to draft a ranking. A recent research project (Schwemmer et al., 2015) aimed at just this topic with providing a list of the most important competitors in the field of less-than-truckload transportation across Europe. As information on this particular topic is not surveyed by any source or database, a list of the most important companies had to be created out of nothing.

3.1.4 Assessing the supply side in logistics markets

As logistics markets and companies are not sufficiently dealt with in official statistics, there is an essential gap for valid assessments of the logistic service provider sector. In need for data on this underestimated business sector, Fraunhofer SCS began to gather data on LSPs in Europe. For more than 20 years now, data has been gathered in exchange with logistics firms. The process includes identifying, cataloging and characterizing respectively profiling logistics companies.

Similar to establishing a list of the biggest firms in an industrial sector, the work to establish a top ranking for the biggest LSPs in Germany is only possible to be achieved by elaborate research work. Primary research on this topic includes identifying logistics firms and evaluating their businesses by surveying those firms concerning their business size, business model and other relevant aspects (like e.g. number of employees, organizational struc-

ture and customer segment focus). While the customer segment focus of a LSP might be easy to assess by the modern means of communication (homepages, company reports, etc.), the real capability of an LSP in doing business in a particular industrial segment can hardly be attained. Thus, collecting primary data is the method of choice.

3.2 The case of the German chemical industry

For Germany, the cost volume of logistics activities in and for the chemical industry is estimated to be about EUR 14 bn in 2013 (Kille and Schwemmer, 2014). This includes logistics activities that are outsourced to LSPs and those rendered in-house by wholesale or industrial firms (not outsourced).

The most important countries for Germany with regard to trading chemical commodities are the Netherlands and Belgium. This is especially attributable to the port of Rotterdam being of significant importance for the European chemical industry.

From a logistics perspective, the balance of trade flows is interesting to analyze as it can have effects

on the kind of logistics services that are available and on price levels of logistics services regarding the trade lane. The decimal numbers within figure 2 represent directional backload factors. These are calculated as the imported measured against the exported tons. A backload factor of 1.0 represents equivalent goods flows in both directions (imports/exports=1). Backload factors that are below 1.0 (resp. above 1.0) show an unbalanced flow of goods with less (resp. more) tons flowing in than out. From a German point of view, the backload factors are 1.62 and 1.53, so that the incoming tonnage from the Netherlands and Belgium is about 50% higher than the amount delivered from Germany to those countries. The probability that backloads can be acquired for outgoing transports from Germany to the Netherlands (resp. Belgium) is high, and vice versa, the risk for an empty run backwards is low. The river Rhine between Rotterdam and Mannheim in Germany is the single most important trade lane for hinterland traffic from the port of Rotterdam.

Time and distance profiles for the mentioned trade lanes are displayed in table 1. As the coun-

Figure 2 Trade lane/cross border goods flow in the chemical industry and probability for backloads between Germany and the Netherlands as well as Germany and Belgium (Kille et al., 2015, p. 161).

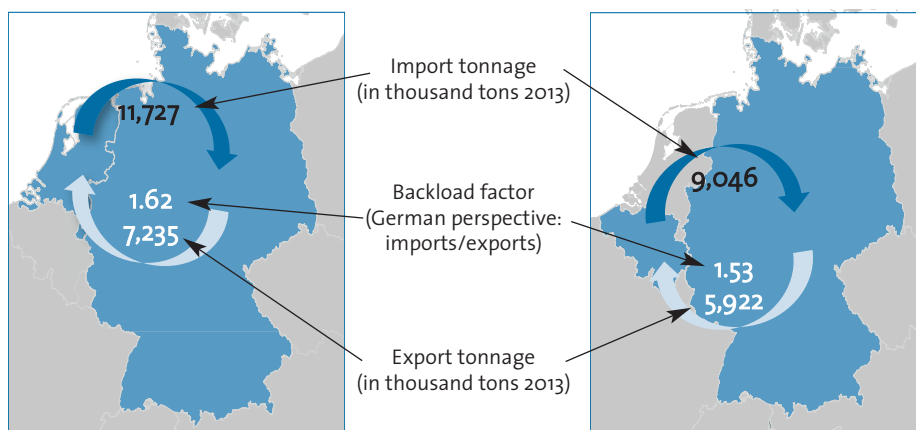


Table 1 Time and distance profiles of important chemical industry trade lanes (Schwemmer et al., 2015, p. 46).

Netherlands - Germany	Belgium - Germany
Distance: ● ● / 662 km / 1,091 km	Distance: ● ● / 773 km / 1,100 km
Time: ● ● / 11 h / 18 h	Time: ● ● / 13 h / 18 h
Infrastructure: +	Infrastructure: +

tries are bordering each other, the minimum distance is set to 0 km by the used symbol (•|•). As shown by the second distance measure, the distance between the countries' capital cities is 662 km resp. 773 km. The third distance measure denotes the furthest distance to connect the countries. Assuming an average speed of travel of 60 km per hour, the displayed time is necessary to travel the distance via road traffic. As the plus symbol indicates, the infrastructural conditions on these trade lanes are good, one can assume that the average speed of 60 km per hour can be reached within these countries.

The **demanders of logistics services in the chemical industry in Germany** are displayed in Table 2. This top 10 list presents the demand side of the chemical logistics market for Germany as a result of a study conducted in 2014 with turnover information available for 2013.

BASF is top of the list with a large turnover and is followed by INEOS' German entity. Basell is ranked third. As Germany is a large economy, the top 10

chemical companies reach turn-over figures that are well above the mark of EUR 1 bn per year.

The products of the companies do not only differ in type but also regarding their requirements for distribution to customers. E.g. Henkel's products are to be found at customers like supermarkets and drug stores, which are mostly located in inner cities, they are purchasable by end consumers. Most of the other manufacturers' products are supplied to other industries in business-to-business relationships and are not specified according to end customers' requirements. The top list mainly includes well-diversified players with a wide range of products involving different handling requirements and logistics services.

The **LSPs that are specialized in the chemical industry** are shown in Table 3. A complex range of produced goods requires a suitable logistics mix. The chemical industry is marked by fluid and bulky goods that are transported inbound to the manufacturers sites. Such sites may represent small and specialized as well as large and complex compos-

Table 2 Top 10 companies in the German chemical industry (Kille and Schwemmer, 2014, p. 163).

Company	Data quality	Turnover in Germany in EUR mn 2013	Turnover worldwide in EUR mn 2013	Employees worldwide 2013	Products/Value chain position
BASF SE	***	23,476	73,973	112,206	Chemicals, plastics, etc. (oil/gas business excluded)
INEOS Deutschland	**	5,124	30,505	15,000	Diversified
Basell Polyolefine GmbH	***	4,867	31,958	13,300	Plastic granules and plastic powder
Dow Gruppe Deutschland	**	3,450	41,236	54,000	Special chemicals, plastics, etc.
Evonik Industries AG	***	3,049	12,874	33,650	Special chemicals
Henkel AG & Co. KGaA	***	2,247	16,355	46,850	Laundry detergent, cleaning supplies, personal care, etc.
Clariant Produkte GmbH	**	2,030	4,956	18,099	Special chemicals
Air Liquide Dt. GmbH	*	2,000	15,225	50,000	Gases
Celanese GmbH	***	1,488	4,728	7,430	Diversified
Lanxess AG	***	1,461	8,300	17,000	Plastics, rubber, etc.

*** corporate data ** partly estimated * estimated

Table 3 Logistics service providers specialized in the chemical industry (Kille and Schwemmer 2014, p. 164).

Company	Data quality	Whole logistics turnover in Germany in EUR mn 2013	Logistics employees in Germany 2013	Worldwide logistics turnover in EUR mn 2013	Logistics employees worldwide 2013	Provided services
Bulk logistics focus (tank & silo, intermodal and value added services)						
Alfred Talke Logistics Services	**	112	900	202	2,000	terminal, tank & silo
Bertschi	*	195	n.a.	830	2,200	bulk, tank & silo, logistics service provider
Hoyer Internationale Fachsped.	**	385	n.a.	1,087	5,067	terminal, tank & silo, logistics service provider
Imperial Logistics (Lehnkering)	***	1,268	n.a.	2,953	n.a.	bulk, tank & silo, terminal
Karl Schmidt	**	250	n.a.	293	n.a.	terminal, tank & silo
Rinnen	***	152	555	202	745	terminal, tank container
RSB Logistic	**	102	127	102	127	terminal, tank & silo
Transpetrol Int. Eisenbahnspeid.	**	130	105	166	n.a.	rail, tank & silo
VTG	***	164	846	227	1,191	rail, tank & silo, logistics service provider
Focus on chemical production/logistics sites						
Chemion Logistik	**	121	1,000	121	1,000	terminal, logistics service provider, tank & silo
Evonik Industries	**	185	n.a.	195	n.a.	terminal, logistics service provider
Infraserv Logistics	***	72	528	72	528	logistics service provider

*** corporate data ** partly estimated * estimated

ite sites, so-called “Verbund sites” as coined by BASF. Such composite sites need own infrastructures that enable efficient internal transportation and value adding processes. In contrast to other industry sectors, a special kind of LSPs emerged from the chemical industry that carries out transports at the composite sites of the manufacturers as location-based service providers. As these are often spin-offs of the manufacturers at site, they mainly provide services for their parent company but might also provide services for third parties.

The included LSPs all hold specialized equipment and assets to provide their services and to handle hazardous goods. Therefore, barriers to entry into these LSP markets are high. Certificates that prove that LSPs are able to handle hazardous goods and fulfill quality standards are relevant to build

trust to possible contractors.

Besides specialized load carriers, there are many generalized logistics services relevant for the chemical industry. The closer the end customer is, the more general is the logistics equipment. For example inbound transportation is often carried out with the use of pipelines, tankers or tanker trucks as bulk transports, the outbound transportation as well as distribution to original equipment manufacturers, wholesalers or retailers are more distinct and can be carried out by parcel or packaged goods carriers. No other industry holds a higher share of inland vessel transportation than the chemical industry with about 10% of the carried tonnages moved by barge. Transportation by train is also noticeably high at 14%, which even grew from 2011 to 2013 by about 1% (Kille and Schwemmer, 2014).

4 Chemical logistics employment

4.1 Methodological remarks

Logistics is often represented by an extra economic section within statistics (section H - Transporting and storage within NACE Rev. 2). This industry code does not obey the cross-sectional characteristic of logistics but encompasses the LSP market. Employees that perform logistics tasks at manufacturers and trade companies are not taken into account. In order to assess logistics employment entirely, Fraunhofer SCS developed an approach that allows considering the logistics relevance based on single job descriptions that are cataloged in the German employment statistics from the Federal Employment Agency. For each job that is classified in these statistics, an individual logistics share was derived (Kübler et al., 2015). Basis for this evaluation are special data sets on the German labor market published by the Federal Employment Agency (Bundesagentur für Arbeit, 2014)¹.

4.1.1 Extracting chemical logistics employment

An extraction of the chemical logistics employment from the statistical basis needs to take into account specific supply chain characteristics of the chemical industry: Handling and transportation of chemical goods and also related administrative tasks occur at chemical manufacturers, chemical trade companies (wholesale) and at LSPs. These LSPs carry out logistics activities that are outsourced by the shipping companies. While the amount of logistics personnel in the relevant manufacturing branches (e.g. “manufacture of coke and refined petroleum products” and “manufacture of basic pharmaceutical products and pharmaceuticals”) can be quoted directly from statistics drawn from the Federal Employment Agency, figures for wholesale and LSPs have to be estimated (Krupp et al., 2013).

4.1.2 Considering administrative and self-employed workers

The first steps of calculation include employees who obviously perform operational logistics activities. Analyses show that - regarding 100 logistics employees - there are 15 additional employees necessary for administrative and management processes in the background (e.g. billing and accounting processes, human resources or management) (Kübler et al., 2015). This results in a 15% increased figure for the absolute amount of chem-

ical logistics employees.

As data from the Federal Employment Agency only considers employees who are subject to social insurance contributions, analyzing logistics employees encompasses some additional steps of analysis. An evaluation of micro-census data, a sample survey covering roughly 1% of the German population (Statistisches Bundesamt, 2014), has shown that the total logistics employment is about 15% higher (Kübler et al. 2015). To account for the high amount of self-employed truckers and parcel distributors in the German logistics market, these workers need to be added to obtain the total amount of employment within the chemical logistics sector.

4.2. The case of the German chemical industry

In 2014, the chemical logistics market in Germany employed about 64,000 workers subject to social insurance contributions; the total employment (including self-employed people) is at about 73,700.

4.2.1 Chemical logistics employees can be found in different economic sectors

A share of 43% of the chemical logistics employees work for manufacturing companies such as BASF, INEOS or Henkel. Further 38% of the employment can be ascribed to LSPs specialized in chemical logistics. At least 19% of the total employees in the chemical logistics market work for wholesale companies, which deal with refinery and chemical products. Regarding the development of employees working at the LSPs, a constant increase can be observed while the number of employees working for shipping companies constantly decreases (figure 3).

These tendencies might be interpreted as a concentration of core competences in the manufacturing sector and a trend to further outsource logistics operations to LSPs. As data for other sectors look quite similar, these tendencies are not only specific for the chemical sector.

4.2.2 Geographical allocation of chemical logistics employees

Regarding the geographical allocation of chemical logistics employees², a strong concentration on Western Germany – besides the area Leipzig-Halle and the south of Bavaria – is visible (figure 4). The highest numbers of employees can be detected close to the known chemical hotspots

¹ This evaluation includes only employees who are subject to social insurance contributions. Therefore, e.g. self-employed people, public officials or marginally employed people are not included.

² The statistical data on employment is structured according to the geocode standard “Nomenclature of Territorial Units for Statistics (NUTS)”. The statistical data on logistics employment in Germany is available on the level of NUTS3, a level of detail of single administrative and municipal districts.

Figure 3 Development of chemical logistics employees working for shipping companies and logistics service providers (Fraunhofer SCS, data from Bundesagentur für Arbeit, 2014).

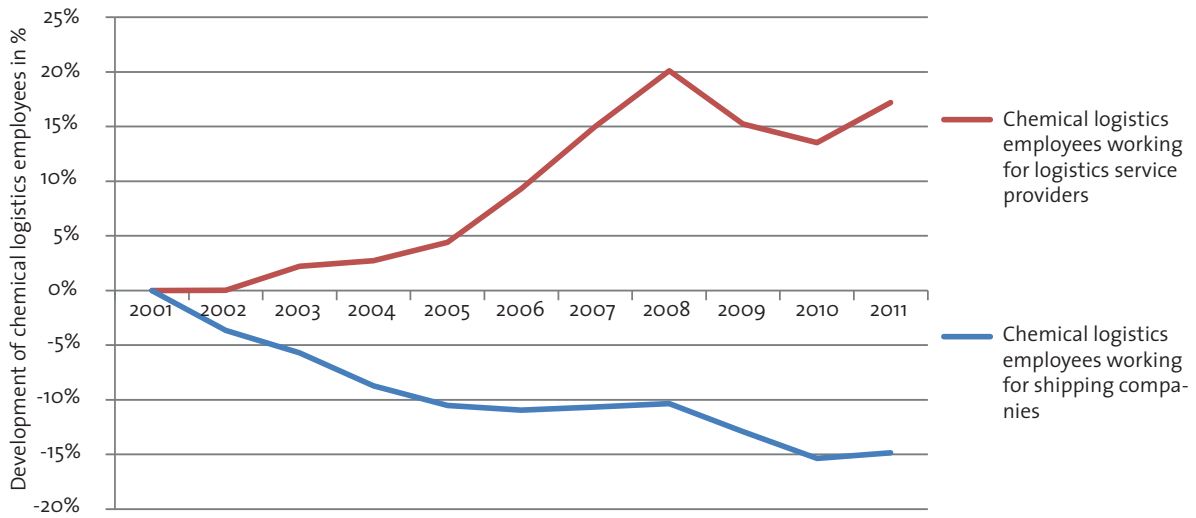
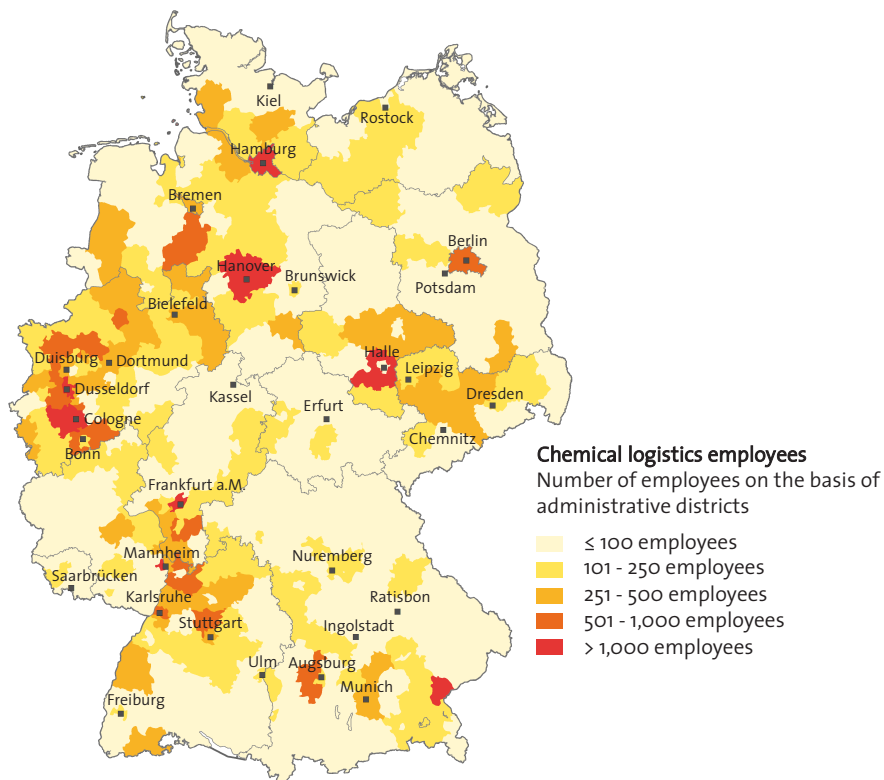


Figure 4 Geographical allocation of chemical logistics employees (Fraunhofer SCS).



like the Rhineland and the metropolitan areas Rhine-Neckar and Rhine-Main. Almost 35% of all chemical logistics employees are working in those regions. While logistics employees (in general) are evenly distributed across Germany, chemical logistics employees are more concentrated. Nevertheless, there are many German administrative districts in rural areas that show a number of 100 employees or more besides the hotspots, e.g. at the border of Hesse and Thuringia in the center of Germany, in the west of Bavaria or in Mecklenburg-Western Pomerania in Northeastern Germany.

4.2.3 Requirements for chemical logistics workers

Chemical logistics offers a broad field of activity. A need for operational logistics activities exists when handling and storing highly diverse materials (chemicals, hazardous materials, liquids, etc.), in the procurement of materials for the manufacturing of chemical products and in the distribution of finished products towards wholesale and consumers. There is also a need for workers who have an administrative support function, like management activities or organizational tasks that are necessary to enable a smooth flow of logistics processes in the supply chain.

The challenges chemical logistics workers have to deal with are the heterogeneity of the handled products as well as the special instructions and safety requirements on hazardous materials. Chemical products show different aggregate states and a highly diverse value density; furthermore, they have to be monitored without a gap through the whole supply chain (Hardt et al., 2011). The high complexity concerning the handled products has led to the establishment of specialized LSPs. Another requirement those workers have to meet is the technical maintenance of plants as logistics employees might take part in manufacturing processes to some extent (Hardt et al., 2011). The deep integration of logistics in the manufacturing process is a reason why shipping companies operate logistics processes within their production plants by themselves. Until now, LSPs mostly take on distribution processes (Krupp et al., 2013).

5 Hotspots in chemical logistics

5.1 Methodological remarks

For the purpose of evaluating and identifying logistics hotspots on a scientific basis, Fraunhofer SCS developed an approach to evaluate logistics attractiveness on the basis of single administrative districts. About 20 different criteria concerning the logistics offer and demand of a district for

logistics services form an evaluation index. The result is an index score for every German administrative district allowing conclusions regarding geographic logistics attractiveness (Veres-Homm et al., 2015).

5.1.1 Monitoring the German logistics real estate market

In order to match the “theoretical” attractiveness of geographic regions with real logistics settlements, nationwide data regarding newly built logistics properties in Germany has been collected by Fraunhofer SCS for about 10 years. Besides building knowledge on where logistics hotspots are located, the database was created in order to monitor and evaluate the development and structure of German logistics real estates. Prior to this kind of primary data gathering, information on logistics hotspots in Germany was only available from market reports of various real estate brokers. These reports mostly published data for the Big 5 sites in Germany (Berlin, Hamburg, Dusseldorf, Frankfurt and Munich), but did not cover the country as a whole.

The database includes about 8,500 data sets about properties which are explicitly used for logistics processes and cover a minimum warehouse space of about 2,500m². Data sets are compiled via monitoring and evaluating press releases and internet-based tender platforms, market reports of business development agencies and real estate brokers. Further information sources are property offerings and exposés in internet platforms. This data collection method enables high transparency levels due to the availability of these resources to the public. So, newly built properties are captured almost completely, whereas data for real estate built before the year 2000 is not comprehensive.

5.1.2 Capturing different characteristics to run structural analyses

For each data set on logistics real estate, the following information is cataloged depending on its availability:

- Exact address to achieve a precise localization in a geo-information system
- Building size
- Land size
- Building year (date of the groundbreaking)
- Number of logistics employees at site
- Investment costs
- Economic sector of the user or in the case of LSPs, if known, the economic sector of the cus-

- tomers (shipping company)
- Further information regarding the building type, the distribution focus of the building or technical equipment (if available).

This database enables different analyses, e.g. of logistics settlements in specific geographical areas, the volume of new constructions of logistics real estate and thereby the dynamics of settlements. The database is also very suitable to evaluate logistics properties of an economic sector - to suggest its local hotspots and its site requirements. Furthermore, it offers the possibility to figure out if there are any specific characteristics, e.g. different sizes in relation to other economic sectors or specific technical features that investors have to consider when letting the warehouse to certain economic sectors.

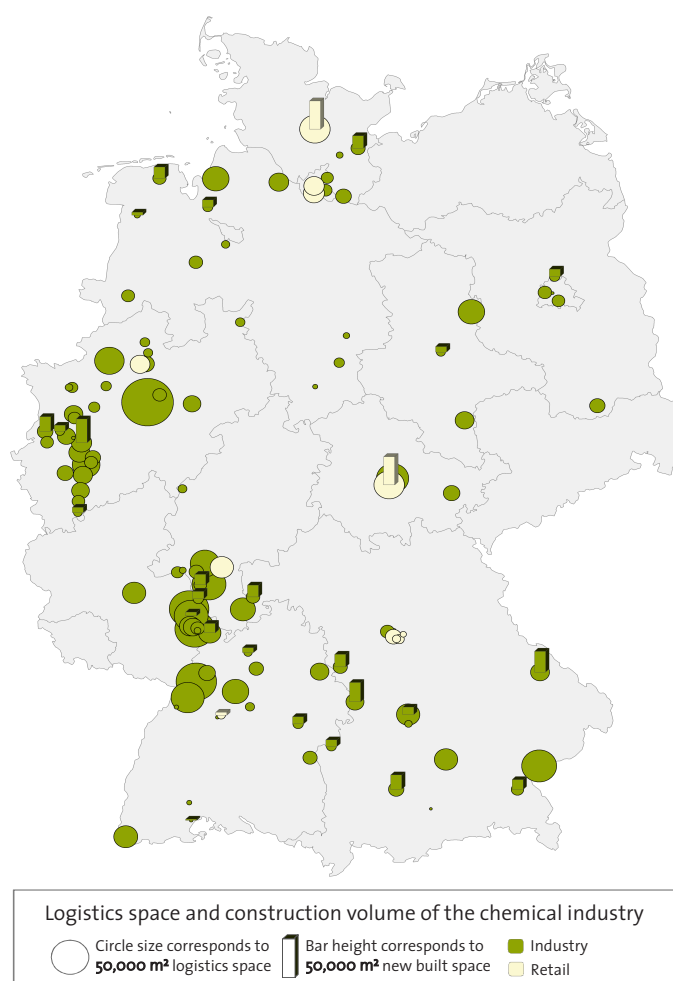
5.2 The case of the German chemical industry

To visualize chemical logistics hotspots, the logistics properties, which are used by manufacturing or trading companies of the chemical industry or by LSPs operating logistics for the chemical sector, can be extracted from the database described in section 5.1.

5.2.1 Visualizing chemical logistics hotspots in Germany

Figure 5 depicts the logistics hubs of the chemical industry. Logistics properties which are solely used for the chemical industry are even more concentrated than the logistics employees (figure 4), who are often located in production plants or in case of wholesale in sales areas. Dominant logis-

Figure 5 Logistics space of the chemical industry (Fraunhofer SCS logistics real estate data-base, evaluation in Q1 2016).



tics clusters exist in Western Germany with the Rhineland, the Ruhr area, the metropolitan areas Rhine-Neckar and Rhine-Main. Further settlement clusters represent Hamburg as central inbound site for containerized goods from overseas, Halle in the middle of Germany and Burghausen in the South of Bavaria. Besides these sites, some distribution centers operated by LSPs can be found.

Therefore, chemical logistics space can primarily be detected close to the historically settled production plants of the chemical industry along the Rhine, which is one of the most important inbound trade lanes for chemical raw materials (Kille and Schwemmer, 2015). The proximity to the shipping company turns out to be a priority for settlement decisions. BASF introduced the term “Verbund site” to express this closeness. According to BASF (2016), the site in Ludwigshafen located in the Rhine-Neckar area is the largest integrated chemical complex and biggest “Verbund site” within the BASF group.

5.2.2 Establishing chemical parks operated by service providers

At the end of the 1990s, in the course of globalization, the German chemical industry had to restructure and reduce its process costs to face worldwide competition. This also led to the relocation of sites from foreign countries. In this context, various chemical parks have grown (Grap and Milnikel, 2011). These sites are operated by a service provider who additionally offers properties, infrastructure, maintenance, facility management and further site services. Examples are the industrial park Höchst operated by Infracor or the chemical park Marl operated by Infracor, formerly Evonik Industries. These chemical parks allow shipping companies to concentrate on own core competen-

cies and to use cost intensive infrastructure like pipelines or rail connection in association with other shipping companies. Furthermore, special conditions such as the storage and handling of hazardous goods and 24 hours operation time are fulfilled (Veres-Homm et al., 2015). Finally, those synergies led to an increase in efficiency and cost reduction (Grap and Milnikel, 2011).

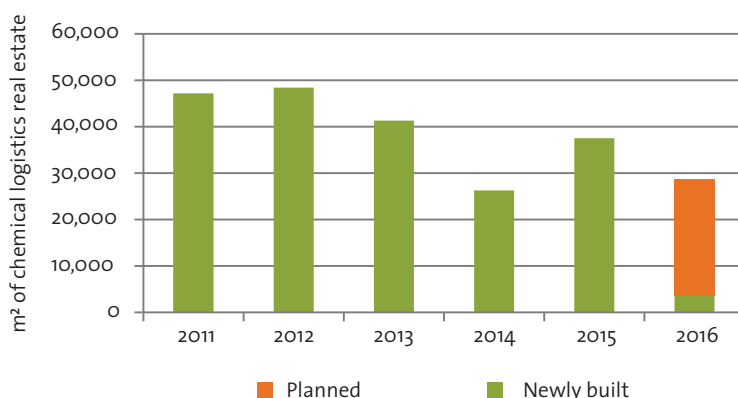
5.2.3 The chemical logistics real estate market

The companies BASF, Dow, Akzo Nobel, L’Oréal, Procter & Gamble and Henkel are the largest commercial users of logistics space within the chemical sector in Germany. Regarding specialized LSPs, Alfred Talke, Alfons Greiwing or Infracor have to be mentioned. Additionally, diversified LSPs play an important role, e.g. DHL, Loxxess, Dachser or Fiege operate a considerable amount of logistics space in Germany (also see section 3.2).

Regarding the construction volume of logistics properties in the last five years, the market for logistics properties in the chemical industry can be rated as small with a yearly volume of about 40,000m² of new settlements (figure 6). Examples for new settlements in the recent past are Estée Lauder in Kerpen, Henkel in Dusseldorf or AlzChem in Trostberg. For the year 2016, further settlements are planned, e.g. Laverana in Barsinghausen.

The new properties are mainly located close to the described chemical industry clusters. Compared to locations outside of dedicated logistics parks, the construction of such settlements in dedicated logistics parks or commercial areas saves long and challenging approval processes to build up property that will be used for handling chemical goods. Besides that, synergies can be leveraged there more easily.

Figure 6 Construction volume of newly built and planned chemical logistics real estate (in square meters) (Fraunhofer SCS: logistics real estate database, evaluation in Q1 2016).



6 Trends in German chemical logistics

There are several developments that either affect the logistics sector or the chemical industry, or both.

Whereas the outsourcing degree of distribution processes within the chemical industry in Germany is already comparatively high, outsourcing in the field of highly complex and integrated logistics offers potential for future growth. Until today, shipping companies are very sensitive regarding the outsourcing of logistics tasks near to manufacturing processes like just-in-time delivery or in picking and packing. But as a higher usage of LSPs will lead to an increase in efficiency and accordingly to reduced costs in the course of a growing global world trade, it might also lead to an increase in competitiveness of the German chemical industry.

Due to restrictions for the settlement of new logistics properties and the given synergy effects, chemical parks will gain in importance in Germany. Potentials can also be found in the common use of IT and especially in a deeper IT-integration of LSPs and shipping companies.

As Germany and other European countries are challenged by the demographic change, the average logistics employee is getting older, and at the same time, less young people get trained. Especially in the field of transportation, the recruiting of truck drivers will become a difficult task. Already today, only 3% of the personnel which is used for transportation and delivery, is younger than 25 years (Bundesagentur für Arbeit, 2014).

Additive manufacturing is a technology on the rise. If this form of production and mass customization gains in importance, the chemical industry might provide raw materials to equip 3D printers. However, this scenario is dependent on the materials required for such digital direct manufacturing processes.

The chemical industry might face shifts in its supply chain and business models as distance trade (e-commerce) grows in importance in nearly every industry. Private customers currently represent a very small share of just above 4% as direct purchaser of outputs from the chemical industry. Therefore, the lever as origin of a paradigm shift is considerably small. As the trend to order via digital means of communication leads to smaller orders with increasing frequency over all industries in their business-to-business relationships, a shift towards a stronger end customer orientation within the chemical industry might occur in the near future.

7 Concluding remarks

According to Baghalian et al. (2013), supply chain planning is changing and firms need to rethink

their role as part of supply chains and not as single enterprises any more. Consequently, supply chains instead of companies compete with each other as mentioned by different research work (see e.g. Cabral et al., 2012 and Christopher, 2000). Thus, supply chain planners need to take into account what the market and customers need (Fisher, 1997) and not only what the products and goods handled might need. Therefore, different concepts like “agility”, “flexibility”, “sustainability”, “resilience”, “robustness” and “leaness” (of supply chains) have emerged in supply chain management research. To be able to manage those different strategic directions comprehensively, data and evaluations from different perspectives become indispensable.

This article's purpose was to provide insights on how practical research work can help to make supply chains transparent from a national economics' point of view. The combination of secondary data and primary research handled with specific designed databases and methods enables the compilation of a multi-layered picture. Especially, surveys among experts and practitioners are essential for knowledge building.

The methods applied in the article fit the German market best due to the expertise of the authors and the available statistics. As supply chains and logistics are multi-national, an international perspective should be taken into account in further research. Furthermore, from a researcher's point of view, the comparability of different industrial sectors should become possible to elaborate cross-sectional best practices.

As the world is developing towards service economies, a service perspective might gain in importance in supply chains that handle goods, just like the chemical industry. There might be a need to align logistics systems, supply chains and networks according to this service economy development in the near future. Researchers as well as practitioners should consider this when planning future supply networks.

References

Baghalian, A., Rezapour, S. and Farahani, R.Z. (2013): Robust supply chain network design with service level against disruptions and demand uncertainties: A real-life case, *European Journal of Operational Research*, **227** (1), pp. 199-215.

BASF (2016): *Verbundstandorte weltweit*, available at <https://www.basf.com/de/company/about-us/strategy-and-organization/verbund/verbund-sites.html>, accessed 31 March 2016.

Bofinger, P. (2011): *Grundzüge der Volkswirtschaftslehre – Einführung in die Wissenschaft von Märkten*, Pearson Education, Munich.

Bundesagentur für Arbeit (2014): *Jährliche Sonderauswertung sozialversicherungspflichtig Beschäftigter im Alter von 15 bis 64 Jahre nach ausgeübten Tätigkeiten der Logistik. Deutschland, Kreise und kreisfreie Städte (regionale Abgrenzung nach dem Arbeitsort)*, Bundesagentur für Arbeit, Nürnberg.

Cabral, I., Grilo, A. and Cruz-Machado, V. (2012): A decision-making model for Lean, Agile, Resilient and Green supply chain management, *International Journal of Production Research*, **50** (17), pp. 4830-4845.

Chae, Bongsug (2009): Developing key performance indicators for supply chain: An industry perspective, *Supply Chain Management: An International Journal*, **14** (6), pp. 422-428.

Christopher, M. (2000): The Agile Supply Chain. Competing in Volatile Markets, *Industrial Marketing Management*, **29** (1), pp. 37-44.

Cooper, M.C., Lambert, D.M. and Pagh, J.D. (1997): Supply Chain Management: More Than a New Name for Logistics, *The International Journal of Logistics Management*, **8** (1), pp. 1-14.

Destatis (2015): Data available at <https://www.destatis.de/>, Statistisches Bundesamt, Wiesbaden.

Distel, S. (2005): *Vermessung der Logistik in Deutschland. Eine quantitative Analyse der wirtschaftsweiten Logistikleistungen auf Basis der volkswirtschaftlichen Input-Output-Darstellung und der Beschäftigtenstatistik*, Deutscher Verkehrs-Verlag, Hamburg.

Eurostat (2015): Data available at <http://ec.europa.eu/eurostat/data/database>, European Commission, Luxembourg.

Fisher, M. (1997): What Is the Right Supply Chain for Your Product?, *Harvard Business Review*, (March-April), pp. 105-116.

Grap, R. and Milnikel, B. (2011): Chemielogistik im Kontext allgemeiner logistischer Anforderungen, in: Suntrop, C. (ed.), *Chemielogistik: Markt, Geschäftsmodelle, Prozesse*, Wiley-VCH, Weinheim, pp. 12-13.

Hardt, A., Clemens, G. and Hinterlang, L. (2011): Standortlogistik für die chemische Industrie, in: Suntrop, C. (ed.), *Chemielogistik: Markt, Geschäftsmodelle, Prozesse*, Wiley-VCH, Weinheim, pp. 227-230.

Kille, C., Schwemmer, M. and Reichenauer, C. (2015): *TOP 100 in European Transport and Logistics Services*, DVV Media Group, Hamburg.

Kille, C. and Schwemmer, M. (2015): *TOP 100 der Logistik - Marktgrößen, Marktsegmente und Marktführer*, DVV Media Group, Hamburg.

Krupp, T., Suntrop, C., Kille, C., Veres-Homm, U. and Heeg, L. (2013): *Chemielogistik. Bedeutung, Strukturen, Dynamik*, DVV Media Group, Hamburg, pp. 10-11.

Kübler, A., Distel, S. and Veres-Homm, U. (2015): *Logistikbeschäftigung in Deutschland – Vermessung, Bedeutung und Struktur*, Fraunhofer Verlag, Stuttgart, pp. 26-37.

Schwemmer, M., Kille, C. and Reichenauer, C. (2015): *“Less-than truckload” networks - The European Market for network based cross border goods flows*, Fraunhofer Verlag, Stuttgart.

Statistisches Bundesamt (2008): *Klassifikation der Wirtschaftszweige*, Statistisches Bundesamt, Wiesbaden.

Statistisches Bundesamt (2013): *Jahresstatistik im Handel: Unternehmen, Beschäftigte, Umsatz und weitere betriebs- und volkswirtschaftliche Kennzahlen im Handel: Deutschland, Jahre, Wirtschaftszweige*, Statistisches Bundesamt, Wiesbaden.

Statistisches Bundesamt (2014): *Mikrozensus – Bevölkerung und Erwerbstätigkeit, Stand und Entwicklung der Erwerbstätigkeit in Deutschland 2013. Fachserie 1 Reihe 4.1.1*, Statistisches Bundesamt, Wiesbaden.

Veres-Homm, U., Kübler, A., Weber, N. and Caesar, E. (2015): *Logistikimmobilien – Markt und Standorte 2015*, Fraunhofer Verlag, Stuttgart, pp. 46-54.

Instructions to authors

In the following we want to present important instructions to authors.

More information can be found on the internet at www.businesschemistry.org. If you should have any further questions, please do not hesitate to contact us at info@businesschemistry.org.

The Journal of Business Chemistry publishes original, refereed material on all aspects of business chemistry. It is devoted to presenting theories and practices of management and leadership in the chemical industry and is designed to appeal to practicing managers and academics.

Manuscripts may be submitted for consideration as research papers, papers for the practitioner's section or as commentaries. All submitted research manuscripts have to contain original research not previously published and not under consideration for publication elsewhere. As it is an international journal, all papers must be written in English.

Authors are required to submit manuscripts via e-mail (submit@businesschemistry.org).

The text needs to be sent in MS Word or rich text-format and needs to include the following:

- contact information of the submitting author (to whom all correspondence regarding the manuscript, including proofs, will be sent)
- information about the other authors (addresses, current positions etc.).

Organization of the manuscript

- Abbreviations should be defined.
- Although the guidelines are flexible, especially for case studies, the manuscript should be arranged in the following order:
 - a) Title, author(s), and complete name(s) of institution(s)
 - b) Abstract
 - c) Introduction
 - d) Methods
 - e) Results
 - f) Discussion
 - g) References

Title page

- List the names of all authors and their complete mailing addresses
- Identify author to whom all correspondence should be sent

References and footnotes

- Citations in the text contain only author's name and date of publication; e.g. (Leker, 2001).
- Full references have to be included at the end of the paper in alphabetical order using the style presented on the internet at www.businesschemistry.org.
- Footnotes should not be used for citation, but can be used for additional notes and explanations.

Authors are fully responsible for the accuracy of their references.

Tables and figures

Tables should be numbered consecutively, have titles and sufficient empirical detail in a legend immediately following the title. Each column in a table is required to have a heading; abbreviations should be defined in the legend.

Figures should have titles and explanatory legends containing sufficient details to make the figure easily understandable. Numbers, letters and symbols used have to be sized appropriately. The abscissa and ordinate should be labeled clearly.

Figures and tables should be sent as separate jpg. - files and MS Excel files respectively.

All tables and figures should be placed at the end, not included within the text, but have their intended position clearly indicated, e.g.: (figure 1 here).

Comments

If you have any comments on articles of the previous issue you are welcome to send them to us as a separate submission. The comments are revised only by an Executive Editor and might be published in the next issue if they suit the academic discussion.

Thank you for your contribution!

