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Letter from the Editor

The role of the chemical industry

A variety of companies contributes to the value creation within the chemical sector covering petro chemicals, basic chemicals, intermediates/polymers and specialty chemicals/pharmaceuticals. The chemical industry is further embedded in a network of various actors, whereby particularly downstream sectors are dependent on the chemical industry's performance. These multi-faceted structures and interdependencies between value chains require the chemical sector to continuously question current solutions and to increase the innovative capacity in order to maintain and enhance the competitiveness of the sector and associated industry branches. The diversity of the chemical industry and its challenges are also reflected by the topics addressed within the present issue of the Journal of Business Chemistry.

The first research paper of this issue "Application development in the process industries" by Thomas Lager and Per Storm presents a framework covering all aspects of application development aiming at mutual developing and adjusting customers' and their customers' products and systems. The conducted survey reveals insights concerning firms' expectations of perceived benefits deriving from application development and emphasizes the importance of allocating resources towards this R&D area.

The second research article "Outsourcing of Pharmaceutical Manufacturing – A Strategic Partner Selection Process" written by Gunther Festel, Mikko De Nardo and Timo Simmen is dealing with both the challenges and potential benefits of strategic outsourcing. Based on a case study of a pharmaceutical company, an ideal process and several criteria that have to be considered in the selection of manufacturing partners are suggested. In order to increase the competitiveness with the help of strategic outsourcing, a supporting organizational structure is required.

The first paper of our Practitioner's Section "Correlation between Sales and Profit Development and Ownership Type in the Chinese Chemical Industry" by Kai Pflug demonstrates that private domestic owned enterprises show a higher performance than state- or foreign-owned firms. By examining data from the China Statistical Yearbook of the years 2006 to 2012, the author identifies the type of ownership to be one reason for different growth trajectories of chemical companies active in China and discusses possible conclusions and recommendations for the affected firms.

In the article "Emerging trends in the Industrial Greases Market", Soundarya Shankar provides insights about the importance and facets of industrial greases. The author elaborates that due to the complex and application-specific composition of greases, there are still opportunities for introducing multi-purpose, customized lubricants and new grease materials. The market study points out that particularly in case of increasing environmental standards, bio-based solutions might have a chance in this already competitive market.

Please enjoy reading the third issue of the eleventh volume of the Journal of Business Chemistry. We are grateful for the support of all authors and reviewers for this new issue. To follow the trend of Online and Open access Journals, this present issue of the Journal of Business Chemistry will be the last one available in print. We are looking forward to welcome you on our website www.businesschemistry.org for the next issue coming up in February 2015.

If you have any comments or suggestions, please do not hesitate to contact us at contact@businesschemistry.org.

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Research Paper

Application development in the process industries

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The process industries span several industrial sectors, such as minerals and metals, pulp and paper, food and beverages, chemicals and petrochemicals, utilities and pharmaceuticals; thus, they constitute a considerable part of the manufacturing industries. In the family of process industries, a substantial part of company research and development (R&D) lies in the area of helping customers use their supplied products more effectively; this area is generally designated application development in the process industries. Based on the findings from a survey of major process companies in Sweden, the results from three previously publications on different aspects of application development have been merged into a coherent framework. The importance of application development to all companies was judged to be very high, and as a mean value, 30% of all company R&D resources were allocated to application development. Most of the companies in this study carried out application development not only with their customers but also with their customers' customers and customers' equipment suppliers. At the extremes, one firm expected 80% of application development to give customers improved products, while the other extreme expected only improved customer process technology. Improving company market shares in the process industries thus depends both on competitive products and on the collaborative development of the customer's use of those products.

1 Introduction

The process industries span several industrial sectors such as minerals and metals, pulp and paper, food and beverages, chemicals and petrochemicals, utilities and pharmaceuticals, thus constituting a substantial part of all manufacturing industries. A key difference between companies in the process industries and other manufacturing industries is the often long, complex and rigid supply/value chains prevailing in the process industries (Tottie and Lager, 1995). Another important difference is that the products supplied -- and often also delivered in the process industries -- are mainly semi-finished materials or ingredients of different kinds, not components. One kind of innovation activity related to such products lies in the area of helping its business-to-business (B2B) customers

to make more effective use of the supplied products, thereby assisting them in improving their processes and products. This area is generally designated "application development" by industry professionals. In this study, the slightly modified definition of application development presented by Lager (2010) has been used:

Application development is not product development but the significant development of the customer's use of the supplying company's products. The development is primarily intended to optimize and to improve the customer's products and/or production system or to give additional opportunities for other customer cost savings.

Application development constitutes the identification of new application opportunities for a firm's existing products and sometimes also the potentially required adaptation of those to new application requirements. Therewith, it is positioned – from the perspective of the application-developing company – at the interface between incremental product development, new business development and marketing.

Application development in the process industries has thus far been scarcely researched, and an initial literature review of publications in this area resulted in surprisingly few hits using the key words “application development”. The meagre results from the preliminary literature survey suggested that the concept needed to be grounded in another kind of conceptual framework, starting with previous research in the areas of inter-firm collaboration, open innovation, supply-chain collaboration and product-service integration (Chesbrough and Crowther, 2006, Schiele *et al.*, 2011, Klioutch and Leker, 2011, Shankar *et al.*, 2009).

The authors' own industrial experiences confirm that companies in the process industries have long since identified this area of development as one of industrial importance. However, there seems to be a scarcity of information or guidelines in academic or industrial publications on this subject area or on how to efficiently manage this kind of development activity. For this reason, a study was initiated in order to close this research gap and investigate different aspects of application development in the process industries with the aim of establishing a first-hand platform of knowledge for further research. Based on the empirical findings from this survey of major process companies in Sweden, the results from three previous publications (Lager and Storm, 2012, Lager and Storm, 2013) on different aspects of application development have been merged into a coherent framework. However interesting the findings from each previously published article did appear, this present review and analysis of the combined results not only emerged as a more holistic and usable industrial framework for company improvements but also created an overall perspective of this topical area to guide further research. The article is organized as follows: In the next section, a synthesis of the previously published articles has been made as a conceptual framework, followed by the research design and study population. The selected empirical findings from the total study are then presented, followed by a discussion of the results and a presentation of the managerial implications. Finally, the conclusions and areas for further research are put forward.

2 A conceptual framework

During tough economic times, companies need new ways to innovate, stimulate growth and drive revenues. By combining a product with service (service in the form of innovation) or vice versa, firms can improve their bottom and top lines (Miller, 1986). Customers increasingly demand integrated solutions that fit their individual needs instead of buying standardized physical goods. Value bundles are, thus, a mixture of physical products and intangible services (Becker *et al.*, 2010), but in such hybrid offerings firms must comprehend which combination is most appropriate (Garcia and Bray, 1997, Gauthier and Meyronin, 2011, Shankar *et al.*, 2009). A study of the competitiveness of the Swedish process industry (Storm and Bellgran, 2006) noted the importance of the meta-product and customer services. A review of product-service packages found that the greater the degree to which firms customize their products, the more they tend to link products and services into packages; its conclusion was that customization enables firms to learn much more about clients' long-term needs (Marceau and Martinez, 2002). This study also showed that many firms in all positions in the supply chains were, in fact, producing packages of goods and services and not just products alone. Services with a direct relation to industrial products are, thus, gaining importance in efforts to evolve from producers of goods to problem-solvers for their customers (Lay, 2002), and Rangan & Bowman (1992) also emphasize the service dimension for producers of commodity-like products. In the process industries, application development is one out of many services a product-supplying company can offer its customers, together with its products.

Figure 1 depicts this by the targeted supplier – customer relation representing a bundle of products and services (Lager and Blanco, 2010). There is, however, an important differentiating aspect between “application development” and normal “technical services” provided by the supplier, insofar as the first is an innovation activity related to existing or new products and the second is support based on already available technical know-how, often addressing problems with malfunctioning existing products. Application development is, thus, a service provided by a supplier as an active involvement in the customer's process and product innovation activities. Referring to Figure 1, one can also note that application development is a service provided solely to B2B customers, since firms supplying products to consumers do not normally engage in application development activities. In Figure 1, application development is depicted as the relation between a supplier of functional prod-

ucts and its customer.

However, it is also not uncommon that downstream commodity product suppliers actively engage in application development in order to secure a long-term market share. Because of that, application development is to be regarded not only as an industrial marketing tool but also as an important a vehicle for understanding customers' and customers' customers' present and future demands on supplied products. Some companies in the process industries are positioned in the middle of long industrial supply/value chains; for this reason, there are a number of candidates for collaborative application development, which is further illustrated in the conceptual model in Figure 2.

Companies may carry out process development, product development and also application devel-

opment apart from other activities like applied research and technical support. The first and most obvious target for the supplier is, naturally, the immediate customers in the supply chain, but application development with the customer's equipment suppliers and end-users may be optional activities. Both functional product suppliers and some downstream and upstream commodity suppliers may benefit from application development. Accordingly, application development, as an institutionalized function in process industry firms, thus focuses on bridging the gap between a product supplier's knowledge of the product's performance scope and the customer's knowledge of its own production process requirements. However, depending on customer needs, application development may not only target the improved use of the supplied prod-

Figure 1 Modelling the supply chain in the process industries from raw materials to finished products at the end-user, adapted from Lager and Blanco (2010).

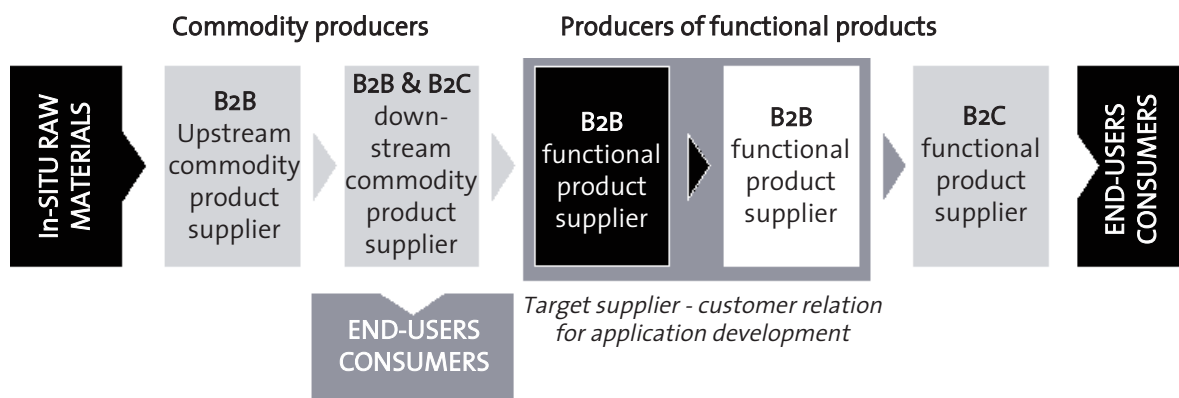
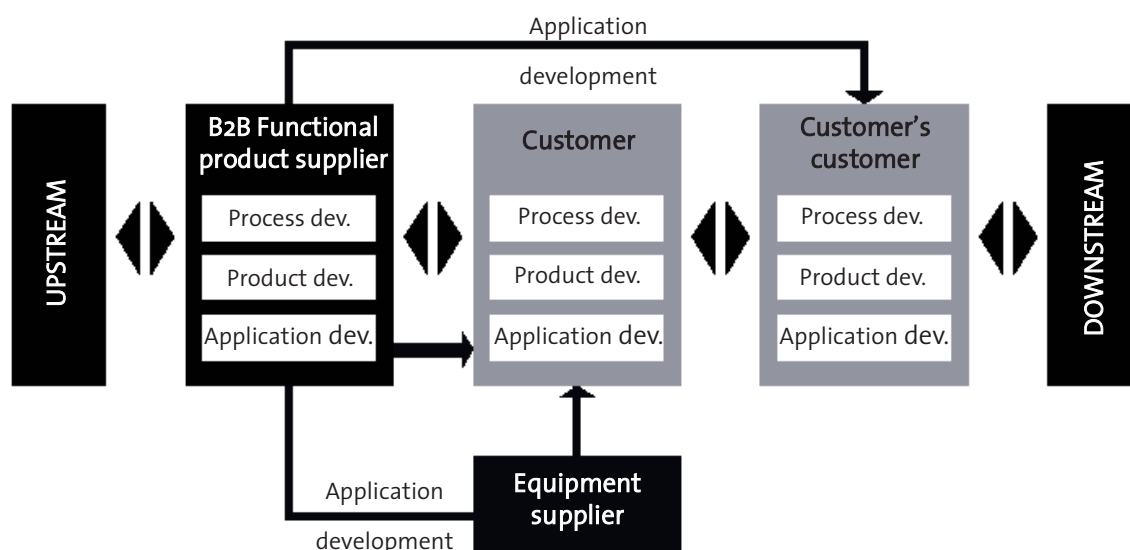


Figure 2 A conceptual model of collaborative application development in the process-industrial supply/value chain. The product deliveries and interactions are symbolized by the double black arrows.



uct (process innovation) but can also target the improved properties of the customer's manufactured products (product innovation). The term "collaboration" between firms emphasizes a long-term, effective and continuous relationship between companies, as opposed to limited transactions and/or exchange of information (Frishammar and Hörte, 2005). Regardless of collaboration mode, however, external collaboration as such has both advantages and disadvantages. Advantages include access to resources, economies of scale, risk and cost sharing, enhanced product development, learning and flexibility (Hamel, 1991). Disadvantages include loss of proprietary information, increased complexity in management issues, financial risks, increased resource dependence, and loss of flexibility (Hamel et al., 1989). Since there are both advantages and disadvantages to collaborations, it is important for firms both to identify their own expected outcomes (drivers) for carrying out application development and to clearly identify expected customer outcomes.

3 The study

Because of the scarce research in this topical area, an exploratory survey was considered as a proper research approach.

3.1 Research design and study population

The questionnaire focused on descriptive information gathering, which is a normal approach when researching new topical areas (Yin, 1994). Although the "population of interest" for the study is the global process industry, it was decided early in this research project to include only Swedish companies from the process industries; these companies became the selected "study population". Since this was an exploratory study, it was decided that the authors' first-hand knowledge of Swedish companies in the process industries would not only aid in the actual conduct of the survey but would also help to define the study population and facilitate contact with knowledgeable respondents in the companies. The selected companies were located in Sweden, not necessarily having their registered offices in Sweden, but with major production sites and other marketing and sales activities in that country. Only companies estimated to have substantial B2B activities were selected, and most of them had customers on the global market, but some had customers only on the European market. Many were major players within their respective industry sectors and had substantial application development activities. The selected companies are presented in Table 1. The industry sectors

included the forest, mineral, steel and chemical industries. The companies were positioned in their industry supply/value chain as either upstream or downstream companies. An upstream manufacturing company is either a producer starting with raw materials or a refiner of raw materials, often into commodities. The downstream producer may then start as a B2B customer for such products, often refining them into more functional products for B2B customers.

3.2 The survey

The questionnaires were distributed after companies and suitable respondents had been located. In most cases, a named person within each company's R&D organization was contacted by telephone before the mailing, but in a few instances the respondents were simply contacted by e-mail with the questionnaire attached. The response rate was 74% out of a total mailing of 23 questionnaires. For some sectors of the Swedish process industries, the survey can be viewed as a census at the time of the inquiry, as all major companies in the Swedish forest and mineral industries responded. The questionnaire was answered by only one individual respondent in each company, but care was taken to identify a respondent with intimate knowledge in the area of application development. However, in some large multidivisional organizations with different products and customers, the answer from one respondent may represent only one part of the organization. Six respondents did not respond to the questionnaire even after several reminders.

4 A synthesis of empirical findings

4.1 Defining the "application development" concept

In the survey, it was important that all respondents answer the questionnaire starting from a common and well defined application development concept. Thus, it was necessary to propose such a definition in the first part of the questionnaire. The option of presenting alternative definitions or asking the respondents to use their own definition was, therefore, not feasible. In order not to give too much of a bias to the question about the proper definition of the application development concept, the respondents were encouraged afterwards both to comment on the definition used and to suggest alternative definitions.

There was very strong support for the proposed definition (Lager and Storm, 2013). Out of the 17 respondents who answered the question, 14 agreed with the definition without adding any further sug-

gestions or comments. Three respondents did not agree. However, two of those respondents did not reject it outright but suggested improvements. "May improve" was considered a bit too weak a formulation in the definition, and it was felt that the outcome of product improvements should be more strongly emphasized.

4.2 The importance and execution of application development

The importance of innovation to long-term corporate survival and prosperity is never questioned nowadays, and this often includes product innovation, process innovation and, sometimes, also service innovation. The area of application develop-

ment is however not yet well recognized. The results from asking the respondents how important this activity was in their company showed that application development is an activity of strong importance to many companies in the process industries (Lager and Storm, 2013). On an ordinal scale (1=No importance; 5=Company top priority), the mean value of 4.2 can be considered a high rating; no rating less than three was given, and five companies gave a rating of five. On the other hand, excellence in application development (1=Very poor; 5=World class) received a mean value of 3.7, indicating that there are possibilities for improvement. Five of the respondents stated that their application development capabilities were only average.

Table 1 The study population of Swedish companies in the process industries.

Industry sector affiliation	Position in the industrial supply chain	Annual turnover (billion Euro)	Main market	Share of the Swedish industry sector
Forest	Downstream (B2B & B2C)	2.0	Mainly European	
Forest	Upstream (only B2B)	1.0	Mainly European	
Forest	Downstream (many B2C)	12.1	Global	Census (all)
Forest	Upstream & Downstream	10.3	Global	
Forest	Upstream (only B2B)	2.2	European	
Mineral	Upstream (only B2B)	3.2	Global	
Mineral	Upstream (only B2B)	4.1	Global	Census (all)
Mineral	Upstream (also B2C)	53.4	Global	
Steel	Upstream & Downstream	4.4	Global	
Steel	Upstream & Downstream	4.2	Global	
Steel	Downstream	21.7	Global	About 40%
Steel	Downstream	0.9	Global	
Steel	Downstream	9.2	Global	
Chemical	Downstream	14.6	Global	
Chemical	Downstream	1.6	Global	
Chemical	Downstream	12.9	Global	About 20%
Chemical	Downstream (many B2C)	6.4	Mainly European	

4.3 Company drivers and expected customer outcomes

4.3.1 Drivers for company application development

There may be different motives, “drivers”, for companies to engage in application development, and the respondents were asked to rate the importance of a list of six potential drivers. This list is presented in Table 2 together with the means and standard deviations (Lager and Storm, 2013). The top-ranked driver was “An opportunity to build long-term sustainable customer relationships and secure future product sales (top line growth)”; it received a mean value of 4.6, and its largest number of fives stands out. The question is, unfortunately, “double-barrelled”, as it covers two areas in one question. However, it clearly gives an important summary of overall objectives for application development. The second-highest-ranked driver, “An opportunity to learn about customer needs and feedback to own product development”, received a mean value of 4.2, indicating another important aspect for application development in a company. It points out that one kind of development work in a company, application development in this case, provides important input to another development area, and, thus, that the company’s development could benefit from a more holistic perspective on different kinds of innovation activities.

4.3.2 Customer expected outcomes of application development

The customer may get different outcomes from

application development, and the questionnaire proposed the two alternatives as an improved production process or improved finished products. From the results presented in Figure 3, it is evident that both product improvement and process improvement are possible outcomes (Lager and Storm, 2013). Because of the limited number of respondents (two companies did miss to answer the associated questions), one cannot draw too definite conclusions from this material, but there seem to be rather different outcomes for individual companies, even within each sector. This may, of course, be related to different positions in the previously presented value chain in Figure 1 but possibly also to the different divisional affiliations of each respondent. The limited scope of this exploratory survey cannot determine which of these is the case. If one were to try to interpret the distribution at all, there is possibly a tendency for more customer product improvement in the steel industry compared to more customer process improvement for the mineral and forest industries. The large span between 100% improved customer processes to 80% improved customer products is interesting to reflect upon, as such.

4.4 Resource allocation and a suggested typology of application development

4.4.1 Allocation of total company R&D expenditures to application development

Figure 4 presents the percentage of companies’ yearly R&D expenditures allocated to application development by the bars shaded in dark grey.

Table 2 Potential drivers for companies to engage in application development.

Drivers for application development	Mean	St.dev
An opportunity to build long-term sustainable customer relationships and secure future product sales, (top line growth)	4.6	0.6
An opportunity to learn about customer needs and feedback to own product development	4.2	1.0
An opportunity to maintain product price margins if “price creep” is common, (bottom line growth)	3.5	1.2
Giving a possibility to obtain a “lock-in” effect and make customers dependent on the firm as a knowledge provider	3.4	1.2
An important part of the “meta-product” or a “bundling tool” for other associated products or services	3.1	1.2
Giving an opportunity to charge part of the costs or even make profit	2.8	1.5

Resource allocation to application development with the customers varies between 5% and 100%, with a mean value of 31%. The results indicate that the various levels of companies' application development expenditures are more related to each company's business environment than to its belong-

ing to a specific industry sector. Since an average of one third of total R&D spending is allocated to application development, it can be concluded that application development is a significant and important area of R&D for most of the companies in this study.

Figure 3 Distribution of expected customer outcomes from Application Development

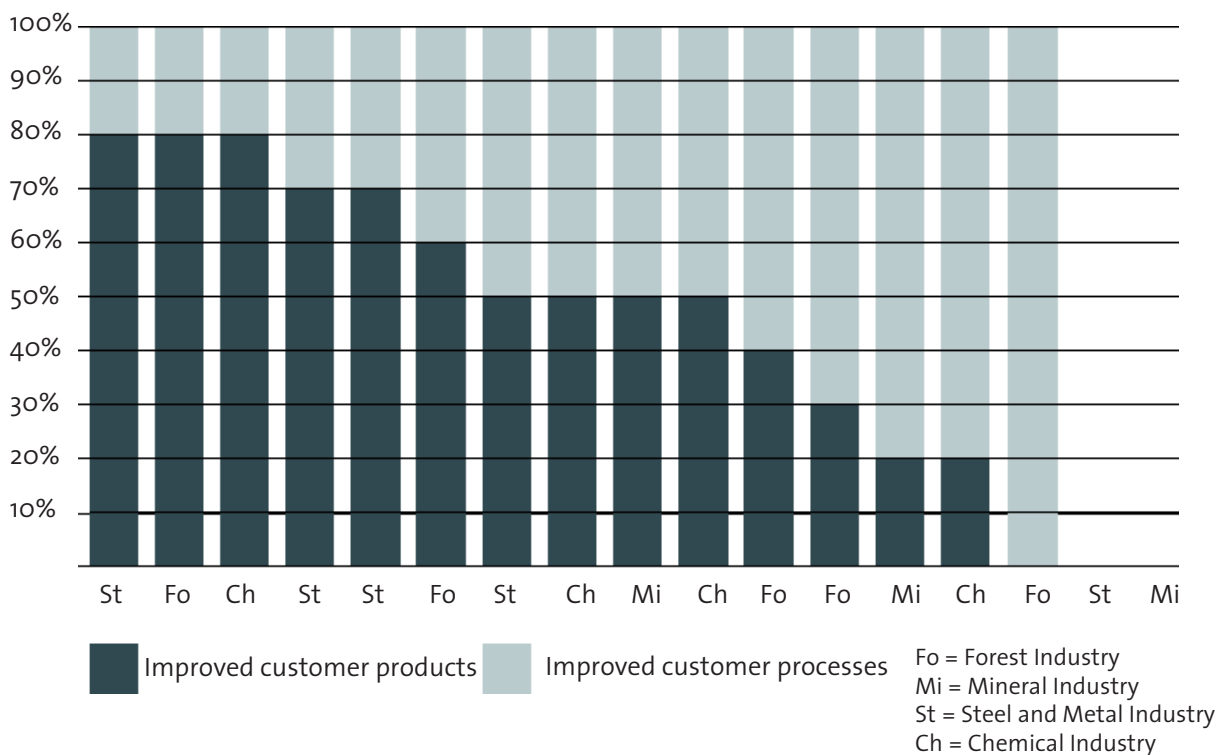
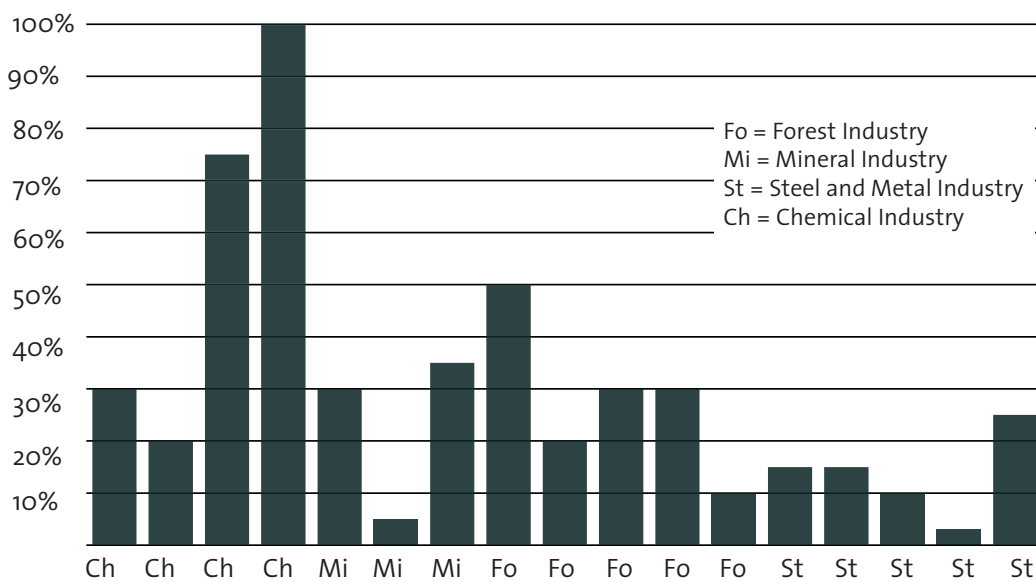


Figure 4 The percentage of companies' yearly R&D expenditures allocated to application development.



The percentage of application development expenditures allocated to collaboration with end-users is illustrated in Figure 5, showing the somewhat surprising fact that nearly all companies (82%) in this study actually collaborate in application development with the customers' customers. Resources for application development with end-

users as part of overall application development expenditures vary from 0% to 65%, with a mean value of 10%. Also in this case, there seem to be little co-variation on an industry-sector level.

Accordingly, the main body of application development for most companies is carried out immediately downstream in the supply/value chain, since

Figure 5 The percentage of application development expenditures allocated to collaboration with end users.

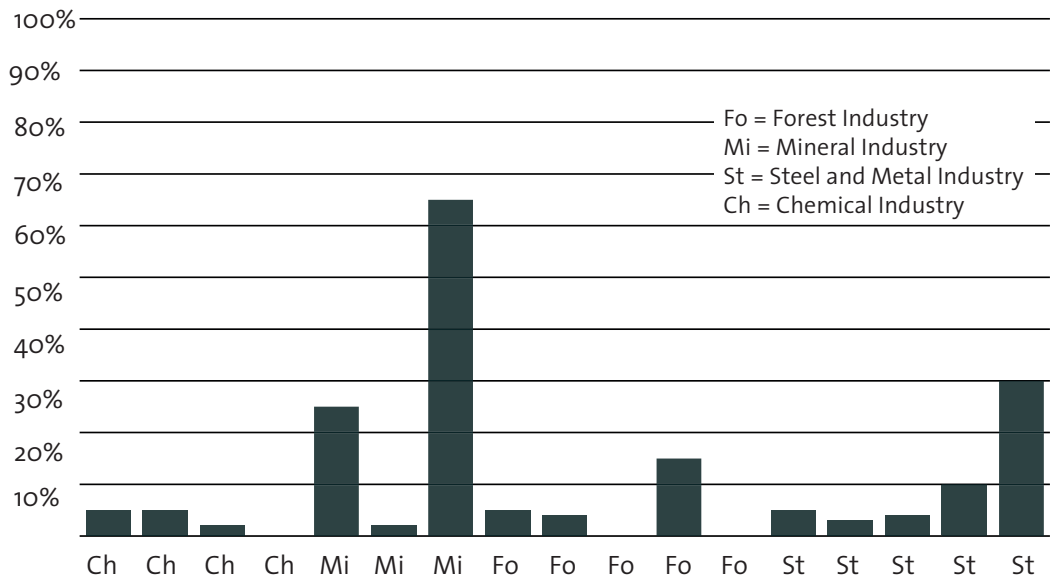
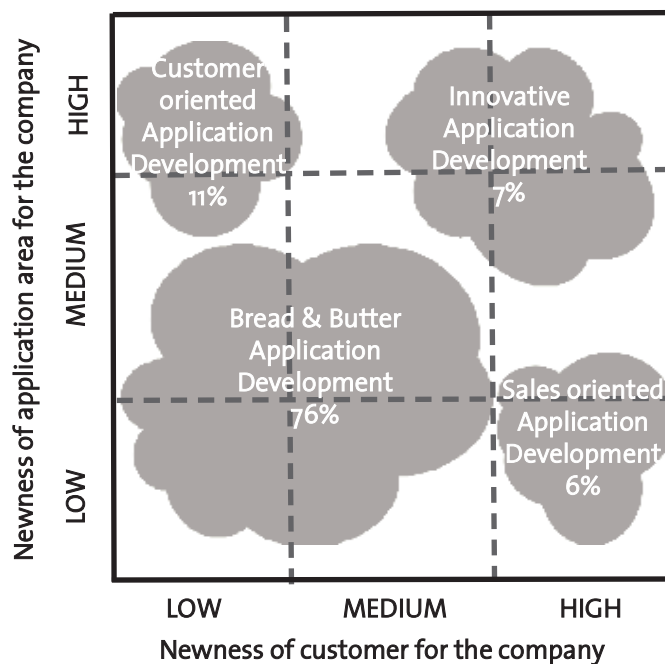


Figure 6 A suggested typology of application development. The figures are mean values of respondents' distribution of resources for application development; adapted from Storm and Lager (2014).



only minor resources are used for collaborative work with the customers' customers (with the exception of one chemical and two forest companies who do not show any application development in collaboration with the customers' customers).

4.4.2 Distribution of company application development resources - a typology

The respondents were asked to position and distribute their company application development expenditures using a matrix presented in the questionnaire. In the results analysis, the structural dimensions and scales from the original matrix were retained, but the number of areas in the matrix was reduced to four, a common practice in sociological data analysis (Barton, 1955). Those four areas were also labeled by the authors in the research results analysis, thereby creating a typology of application development areas and of customers' different levels of newness. Figure 6 presents the results, where the figures are mean values. Selected associated comments from the respondents regarding the different areas of the matrix (presented in the following in italics), guided and highlight the labeling of the different matrix areas.

As presented in Figure 6, the main body of application development is carried out together with well-known customers and as application development of little newness to the company. The area "bread and butter application development" can thus be looked upon as a "comfort zone" for application development, since it seems to be an easily accessible area for application development. This area is obviously the "schwerpunkt" and focus for application development to which most company application development resources are distributed. One comment from the respondents:

This is where most application development is done with old customers improving the use of the supplying company's products. Application development in this area is focusing on cost effectiveness for both suppliers and customers. It is very important to have a good and open relationship with customers, in which you can discuss their process problems and try to find solutions to them.

The area "sales-oriented application development" can be looked upon as a "grey area" when it could be partly agglomerated with other business- and marketing activities. However, the different competence profiles of people involved (Lager and Storm, 2013) merit the inclusion of these activities as true company application development. One

comment from the respondents:

This is a natural area for companies expanding into new markets and using application development experiences to develop new customers.

The area "customer-focused application development" is analogous to the sales-oriented application development area. The cost-efficiency perspective and desire to retain existing customers may explain the higher figure in this area compared with that of sales-oriented application development. One comment from the respondents:

This is a truly customer-focus area, when you follow your (hopefully important) customers in their development activities. Application development in this area has a high chance of success because you can move into uncharted waters with a trusting and trustworthy partner. A key application development area to be in, when moving into new applications.

In the area of "innovative application development", it is possible that the overlap between product development activities is more common, since the newness of the application development area in combination with new customers may result in a need for more product adaptations. One comment from the respondents:

This is innovative application development in need of joint company internal technical and marketing efforts in the innovation process in order to implement new applications with new customers. A high-risk area but also with a high reward potential.

After using the matrix, the respondents were asked about its usefulness for the characterization of different kinds of application development. The mean value was 3.4, making it evident that the matrix did not appeal to all respondents; however, some respondents believed it was very useful, since 55% of the respondents rated the matrix with 4s or 5s.

4.5 Selection of collaborative partners

Table 3 presents a summary of the empirical results. Around one third of companies' total R&D resources are allocated to application development as defined in this study and the figure for the Chemical industry stand out. Referring to the second column, the bulk of those resources are spent immediately downstream since the figures in this column show that only average 10% of the company

resources for application development are spent on application development with the customers' customers. Referring to the previously presented Figure 6, those resources are mainly allocated to well-known customers and application areas (the "bread and butter" area of application development). The companies in the chemical industries and, to some extent, the forest industries, stand out in terms of the amount of total resources allocated to application development and the amount of resources spent immediately down-stream in the supply chain. In column 3 it is shown that the majority of all companies in this study carry out application development with the customers' equipment suppliers. This indicates that collaboration between companies in the process industries and equipment suppliers is an important activity and an area of interest for further research (Lager and Frishammar, 2012).

4.6 Success factors and the application development of excellence

Success factors for application development have been structured on three firm levels: strategic success factors, tactical success factors and operational success factors (Lager and Storm, 2012). Company strategic success factors are those for application development related to decisions and behaviour on the firm group level or R&D top management level. Tactical success factors in this study are those related to the capabilities of the application engineer and the personal traits of the application developer of excellence. Finally, operational success factors are those more related to the behav-

our of application engineers in the context of, and collaboration with, customers.

4.6.1 Strategic success factors

The respondents were asked to suggest potential areas for further improvement of their firms' application development on a strategic level. Several of these were left blank, possibly because they shared the same view as some other respondents who said outright that this kind of information was confidential. However, some of the respondents came up with suggestions for strategic success factors, presented as follows:

- Application development ought to be included in the company's business development activities and strategic planning.
- Necessary resources should be dedicated to this area, and they should be better co-ordinated in large companies.
- Potential areas for application development should be analysed better in order to identify opportunities that may have been overlooked, like improved logistics and material handling. Get away from too many inside-out perspectives.
- Start a separate application development team focusing only on the development of new applications (becoming a trend-setter).

Table 3 Summary of empirical findings related to collaborative partners.

Industry sector	R&D expenditures allocated to application development	Percentage of application development expenditures allocated to development with the customers' customer	Percentage of companies that carry out application development with the customers' equipment suppliers
Chemical	56%	3%	50%
Mineral	23%	30%	100%
Forest	28%	5%	80%
Steel	19%	11%	80%
Total	31%	10%	82%

- There is a need for a better evaluation of the firm's application development and project screening methodology, also from an economic point of view.

4.6.2 Tactical success factors

The respondents were asked to characterize the present and future "application engineer of excellence" (Lager and Storm, 2012). This part of the questionnaire generated many traits of such a person; the following statement gives a flavor of the respondents' answers:

The application development engineer should first of all have an excellent knowledge about the customer's production processes and preferably own experience. It is important that he/she understands that each customer is "unique" and thus that the first move is to comprehend this uniqueness. The person should preferably have a university education as a platform.
Product Manager, Company F

All answers were treated using an affinity technique, and the total answers were thus reduced into the four areas (italics) introduced as follows. *An engineer with a solid background*, preferably with a university education as a platform and recruited, if possible, from the customer industrial sector rather than from one's own ranks. As such, the person should have an excellent knowledge of the customers' production processes but additionally have a good commercial knowledge and business sense. In order to be able to carry out efficient application development, he/she must possess *strong project management skills*. That includes a strategic skill in project selection and a capability to "drive" his/her own organization more than the customer's organization and a capacity to complete started application development projects. Finally, the person should possess an eagerness to achieve results and an ability to work closely with marketing people. The application developer must be *socially competent* and generally pleasant behaviour is desirable, such as a quality of listening to the customer in order to understand his needs but also an ability to communicate well internally and with the customer.

The application developer must have an attitude that transfers a "win-win" application development goal to the customer and, last but not least, the application developer of excellence must have an *innovative personality*. The following traits were mentioned as belonging to such a personality:

- A capacity to generate good "key ideas"
- An open mind ready for new ideas
- Trustful and reliable in customer relations
- An easy-going and optimistic nature
- Having a general philosophy that each customer is unique and that the first move is to understand this uniqueness
- An instinctive behaviour of trying to imagine the impact of improved use of products supplied to the customer

Collaborating in either product or process innovation at the customers' premises is presumably a rather difficult undertaking that requires long experience by an application engineer. The respondents presented a list of personal qualities and skills that support this notion. It is, thus, not only necessary that the application development engineer have a solid engineering background and expert knowledge of the customer's product and process technology but he/she must also have strong project management skills, be socially competent and, probably foremost of all, be innovative! The conclusion is, thus, that selecting or recruiting such a person into an organization is an activity of strong importance and, thus, also very likely to be an important tactical success factor for application development.

4.6.3 Operational success factors

Table 4 presents operational success factors in ranking order of the number of fives from the respondents. The top-ranked success factor received 12 fives out of 17, while the lowest-ranked received only 3. Out of the 15 potential success factors, the three top-ranked ones were:

- 1) Respect for the customer and the customer's arguments and points of view;
- 2) No problem for personnel to visit the customer's production site (willingness to travel);
- 3) Ability to estimate the process and product benefits for the customer (customer's "value in use").

Being a good listener is a virtue that is often preached by salespeople as a way to discover a customer's needs. The second success factor stresses the importance of visiting the customer, a fact that

may sound trivial but, nevertheless, is the most important prerequisite for every successful application development project. The third success factor points out the importance of trying to estimate customer benefits received from application development.

5 Discussions and managerial implications

If a company recognizes the topical area of application development as relevant and important, it is recommended that it should not only be dis-

Table 4 Success factors for application development presented in ranking order using number of fives.

Success factor	No. of fives	Total Forest Mineral Steel Chem.					
		Mean	Std.	Mean	Mean	Mean	Mean
A respect for the customer's and arguments and points of view	12	4.7	0.5	4.8	4.3	4.6	5.0
No problem for personnel to visit the customer's production site (willingness to travel)	10	4.4	0.9	5.0	3.7	4.0	4.7
An ability to estimate the process or product benefit for the customers' customer's „Value in use“	10	4.2	1.2	4.8	4.3	3.4	5.0
An understanding how the company's own product will function together with the customer's other raw materials or commodities	9	4.4	0.7	4.8	4.3	3.8	4.7
A good knowledge of the company's own products and their applications (an intimate understanding when the company's own product is functioning well or not so well for the customer)	8	4.4	0.6	4.4	4.7	4.4	4.0
Regular Application Development meetings or seminars with the customer	8	4.1	1.0	4.6	4.0	3.6	4.3
An ability to select the proper form for contacts; a good speaking partner (meetings, seminars, etc.)	7	4.0	1.1	3.8	4.7	4.2	4.0
An ability to select the proper form for development (more or less formal projects, trouble-shooting, etc.)	7	4.2	0.8	4.4	4.3	4.0	4.0
Easy for customers to contact company representatives for Application Development	7	3.9	1.2	4.4	4.3	3.4	3.0
Not afraid to make suggestions for new solutions to the customer (self assured)	7	4.3	0.7	4.8	3.7	4.4	4.3
An ability to reach a mutual agreement on where to conduct the development work (at own company's test facilities, customer test facilities or other external test centres)	6	3.8	1.1	4.6	3.7	3.8	3.3
An ability to select the cheapest and/or best test environment for the application development project (simulation, laboratory, test work pilot plant test work or tests in the customer's production plant)	5	3.4	1.3	3.6	3.0	3.4	4.0
A transparent work process that has been communicated well to the customer	4	3.6	1.0	4.4	3.3	3.6	2.3
A good command of the customer's language or preferred second language	4	3.9	0.9	4.4	4.0	3.8	3.7
Flexibility in working hours with the customer	3	3.3	1.0	3.2	3.3	3.6	3.3

cussed on an R&D management level but also be elevated to the group management level, taking a fresh look at the company's present application development activities and also reviewing project screening and resource allocation. It is also suggested that the company could use the presented results from this study in their own improvement efforts, not only to develop complementary company-specific drivers for application development but also to benchmark the importance for the company of the potential drivers presented in this article. On a *company strategic level*, it is important to distinguish between supplier-customer collaborations on a project-by-project basis and collaborations on a strategic level, when application development is viewed from a long-term, holistic perspective. On a *company tactical level*, since application development often requires a substantial share of the supplying company's technical resources, it is also important to carefully analyse with whom to collaborate. The presented matrix has, then, the potential to be useful in discussions of what application development is all about and with whom to collaborate, thus helping to "projectify" such development activities. It might then also be appropriate to consider whether the balance between different types of application development activities is good or, conversely, whether strategic changes are needed in the future.

Since collaborating in either product or process innovation at the customers' premises is presumably a rather difficult undertaking requiring long experience, the company ought not only to be constantly on the lookout for persons with such skills but should also plan skill development of existing staff that includes providing proper supplementary training, if needed. The list of potential personal traits for an application development engineer could be an embryo and a template for exploring this area further; it could also be developed into some sort of benchmarking instrument for management use in discussions with the staff. The rated list of operational success factors, together with the list of new potential success factors for application development, can be used as a guideline and trigger for internal discussions of good behaviour on a more company operational level. The application engineer, with an intimate knowledge of the company's products and their uses in the customers' production processes, is in an excellent position to set up development activities in collaboration with the customer's production experts in order to improve the customer's overall production economy and to add value to the customer's production system. Improved use of the supplying company's products on the customer's premises may, however, also give interesting opportunities to improve

and add value to the customer's products. The latter is an area probably not so well explored in some companies, since it requires good relations not only with the customer's process development organization but also with its product development teams. A company that today focuses on either product or process innovation as customer outcomes could possibly benefit from reflecting on whether the other alternative is also worth exploring. Depending on whether the target is product or process improvements for the customer, this may possibly require different application development strategies and, by extension, different skills in application development.

6 Conclusions and further research

Improving company market shares in B2B customer relations not only depends on competitive products but also on the collaborative development of the customer's use of those products. The importance of a company's product and process development is not usually questioned at the top management level, and the results of this study suggest that application development should also be considered a complementary and important aspect of company R&D in the process industries.

This has been illustrated in Figure 7, and the study area has because of that been given a black shading. Another area of importance for companies in the process industries is raw-material development. This area is not normally discussed and has thus been given no shading at all, symbolizing that this is a "white space" on the R&D Management research map for the process industries. It is important not only to balance company total resources and capabilities for all four different development activities well but also to improve company work-processes that facilitate their integration and synergy. The arrows to the right in the figure are thus symbolizing the material flow, while the arrows to the left are symbolizing the necessary flow of information and customer demands that should be progressed backwards into the company organization.

However, the outcome of application development in collaboration with company customers may vary significantly in the "customer process/customer product" development space. Whether improving the customer's product performance (top-line growth for the customer) or reducing the customer's process costs (bottom-line growth for the customer) or both, the area of application development should be considered in the future as a development area of importance equal to that of product development and process development in the process industries.

Moreover, product development projects in the process industries may, in a three dimensional development space, also contain a share of process development and application development. Because of that, it is important not only to balance company total resources and capabilities for all three different development activities well but also to improve company work-processes that facilitate their integration and synergy. Application development, as an institutionalized function in firms in the process industries, focuses on bridging the gap between a product supplier's knowledge of the product's performance scope and the customer's knowledge of its production process requirements and demands on delivered products. Therefore, identifying the required capabilities for mediating between these knowledge pools is highly relevant and seems to be a missing piece in the collaboration and open innovation management literature. One limitation of this study is that the study population includes only process companies that are based in Sweden. However, because most of them have production plants and customers on a global market, it is argued that the research findings may be relevant and of value to the larger worldwide population of interest.

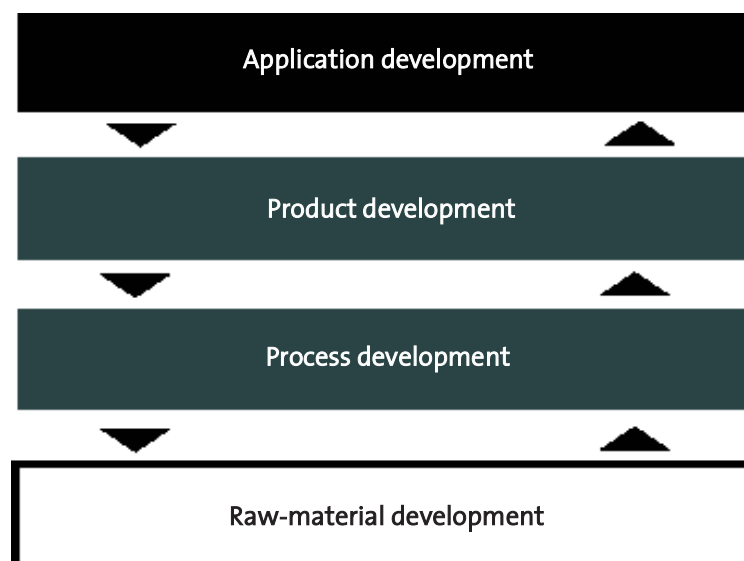
Not only does this look like an interesting new avenue for further research, but the present research results can already give initial suggestions for company improvements. It is evident from this study that both product and process improvements are possible customer outcomes from application devel-

opment. Since most studies on supplier-customer relations focus only on product innovation improvements for the customer, the findings are new evidence that ought to be considered in further research. The different possible targets for the application developer may thus require quite different approaches and personal capabilities, which may be of interest for further exploration. Because application development is mainly carried out at the customer's premises, sometimes in a close collaboration with equipment suppliers and customers' customers (end-users), the development of formal work processes for application development is recommended for further research. Prior research has paid less attention to innovation in the process industries than to innovation in other manufacturing industries. Previous research on managing innovation in the process industries has focused mainly on product development and to a lesser extent on the area of developing new process technology. Application development is now another area that should be added in innovation management research.

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Figure 7 Application development as a strategic innovation activity in the process industries.



comments and important suggestions.

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Research Paper

Outsourcing of Pharmaceutical Manufacturing – A Strategic Partner Selection Process

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The pharmaceutical industry is a growing industry, but companies struggle to capitalize on this growth because of a variety of challenges: shortening patent lives, strong pressure on prices, strict regulations, and the shifting of growth to emerging countries. Outsourcing of manufacturing is increasingly seen as a way to reduce operating costs and improve competitiveness. But external manufacturing is moving away from a purely opportunistic approach of transferring overcapacity to external partners or outsourcing of manufacturing to low-cost countries to reduce costs towards a more strategic approach, where external service providers are seen as partners. The ability to establish and manage strategic partnerships is seen as a key competence. This paper addresses this aspect and focuses on strategic partnerships to increase competitiveness of large pharmaceutical companies by outsourcing activities from chemical production through partly finished products to finished goods packaging. An action research approach was used based on a single case study of a global leading pharmaceutical company. A partner selection process consisting of seven consecutive steps, including the criteria for the partner selection, was developed for pharmaceutical companies with their highly regulated, quality focused manufacturing processes and history of vertically integrated production. It was also shown that, besides having the right process in place, the appropriate organizational structure has to be established.

1 Introduction

The outlook for the pharmaceutical industry is promising (Ernst & Young 2010; Price Waterhouse Coopers 2011). The 2009 market of \$775 billion US-Dollar is expected to grow to over 1 trillion in 2014 with 6% annual growth. Probably the single most important driver in the pharmaceutical industry is time-to-market (Shah 2004). As a consequence, pharmaceutical companies have focused their skills on drug discovery, development and marketing. This is also reflected in the increasing numbers of scientific publications on management of R&D in the pharmaceutical industry (Piachaud 2002; Hess and Rothaermel 2011; Bianchi *et al.* 2011a; Bianchi *et al.* 2011b; Festel 2011; Schuhmacher *et al.* 2013).

But although the industry is growing, major pharmaceutical companies struggle to capitalize on this growth, because they are challenged by a variety of trends (Shah 2004; Fujiwara 2013). There are shortening patent lives and even active patents provide lower barriers to entry, because there are many product alternatives in nearly all therapeutic areas: either alternative compounds (“me-too drugs”) or off-patent generics. The traditional blockbuster sales model is likely to disappear. There is strong price pressure for health expenditures, as those who pay for health care are exerting strong price pressure and influencing prescribing practices. This means, for example, that in order to be approved, new drugs must address new therapeutic areas or have very significant cost or health ben-

efits as compared to existing treatments. These industry trends put pressure on the margins and have made it difficult for today's companies to fight the competition in terms of profits. This suggests a need to find new and alternative ways of gaining a strategic and competitive advantage. One aspect is the significant changes in the area of supply chain management within the pharmaceutical industry. There is a general trend for companies to divest excess capacity resulting from having many local manufacturing sites, and to move towards a global supply chain management process. Whereas in the past the ability to deliver and reliability were important, today cost efficiency and flexibility are key factors for pharmaceutical companies (Verhasselt *et al.* 2012). Currently, the cost of logistics in the sector is relatively high (Song and Wang 2009; Kumar *et al.* 2009; Lowman *et al.* 2012), particularly due to supply chains often having been optimized in accordance with tax or transfer price concerns. One of the main challenges, once the product is on the market, is to ensure responsiveness to fluctuating customer needs. Developing and managing sources of supply is a challenging process especially for pharmaceutical companies with their quality focused manufacturing processes and history of vertically integrated production (Bhadoria and Rajpal 2011). Booth (1999), amongst others, states that there is a welcome move away from viewing the supply chain as merely having to deliver security of supply at minimum cost, to a recognition of its ability to generate additional value for the companies, if they choose the right partners. As the final responsibility for the product remains with the pharmaceutical company, it is crucial that the outsourced business is well controlled (Fields 2004). The importance of choosing the right contractor cannot be exaggerated, as some of the largest pharmaceutical recalls have been due to inadequate effort when selecting or monitoring contractors (Waggener 2003).

As research oriented companies concentrate on discovery and development activities, they rely more and more on external partners. One approach is to establish strategic partnerships in other areas. These are established for various reasons: to obtain access to knowledge and new technologies, to obtain access to new markets or expand global reach or for horizontal or vertical integration in the value chain (Zhang *et al.* 2013). The partners use synergy effects and combine their strengths to aim for growth and profit enhancement or improved cash flow. The ability to establish and manage strategic partnerships is seen as a key competence (Bath 2003). Based on a survey of US, UK, and continental European companies, Kakabadse and Kakabadse (2005) concluded that the best run companies of

the future will focus more on establishing strategic relationships with a number of key business partners. The results strongly indicate that partnership alliances and performance driven contracts will become as important as the current preferred, trusted supplier relationship. But strategic partnerships raise questions concerning intellectual property ownership, technology transfer, hiring away of employees, splitting of profits and expenses, duration and termination of the relationship, risk of capital investments and many other business issues. The relationships are often complex as a result, and can be subject to extensive negotiation.

The decision making often does not follow a structured approach and is not pursued in a systematic way, or processes are just borrowed from other industries. As the product life cycle in the pharmaceutical industry is longer, more highly regulated and more complex than in other industries (Gu and Li 2010; Bhakoo *et al.* 2012; Citron 2012; Ren and Yeo 2006; Lee 2007), there is a need for a specific and customized partner selection process for this industry. But a surprisingly large number of pharmaceutical companies do not have defined processes for finding, choosing and managing contract manufacturers (Linna *et al.* 2008). Whereas there are several research papers focusing on partner selection processes in general (Ding *et al.* 2013; Lau and Wong 2001; Crispim and Pinho De Sousa 2009; Diestre and Rajagopalan 2012; Li *et al.* 2008; Zolghadri *et al.* 2011) or on the partner selection process in other technological fields (Ramani *et al.* 2001; Collins and Bechler 1999; Wittstruck and Teuteberg 2011), there is a lack of industry specific strategic partner selection processes for the pharmaceutical production processes in the academic literature (Chen and Hung 2010; Zhang *et al.* 2013).

To close this gap, this paper focuses on strategic outsourcing, i.e. the establishment of strategic partnerships for outsourcing manufacturing in the pharmaceutical industry. Strategic outsourcing is bringing in external service providers to manage essential tasks that would otherwise be managed by in-house personnel. In contrast to opportunistic outsourcing this means that this is done on a strategic level, i.e. to realize strategic goals of a company and not only as a tactical tool to use outsourcing on a short-term project basis to realize cost reduction potentials. This paper describes the selection of strategic partners for the manufacturing process, in particular within vertical partnerships of large pharmaceutical firms that have the manufacturing capacity but decide to outsource production for strategic reasons. Accordingly, the research questions addressed by this paper are as follows.

RQ 1: How can a strategic partner selection process for pharmaceutical manufacturing be defined and implemented?

RQ 2: What are criteria for the partner selection within such a process?

An action research approach was adopted to develop the partner selection process based on a single pharmaceutical manufacturing case study in collaboration with a pharmaceutical company belonging to the top ten global companies in this sector. The paper is structured in the following way. In section 2, the theoretical background regarding strategic partnerships and especially supply chain partnerships and outsourcing manufacturing in the context of the pharmaceutical industry is described. The research methodology is described in section 3. Section 4 provides the results and discussions, i.e. the partner selection process including the criteria for the partner selection. Finally, in section 5, the conclusions from the research presented in this paper in relation to the learnings from the analysis of the theoretical background are summarized and the outlook for future research is discussed.

2 Theoretical background

After describing types of collaborations and partnerships the role and importance of outsourcing in general are explained and outsourcing of manufacturing activities, especially in the pharmaceutical industry, is discussed.

2.1 Types of collaborations and partnerships

The types of collaboration can be classified according to various criteria. One option concerns the inter-business relationship – either vertical or horizontal co-operation. Horizontal co-operation is the most frequently used kind of collaboration, where companies collaborate with companies in the same value chain step and maximize the strengths of each company. Such co-operations can be found in partnerships where each partner brings its unique strengths to bear. In vertical co-operations, companies co-operate along the value chain. In the pharmaceutical industry, this form of co-operation can be found in joint efforts to develop and commercialize new products. In the past, pharmaceutical companies were characterized by a relatively high level of vertically integrated production (Bhadoria and Rajpal 2011). As the pace of change is increasing in many industries and product life cycles are shortening, the flexibility to establish partnerships according to business opportuni-

ties is becoming more and more important. This has led to the new company concept called virtual enterprise. This is defined as a temporary alliance of businesses that come together to share skills or core competencies and resources in order to better respond to business opportunities, and whose co-operation is supported by computer networks (Jung 2008). Byrne (1993) points out that this could even involve competitors in other fields that work together for a particular business opportunity to share costs and skills and to access one another's markets. It will have neither central office nor organization chart, nor hierarchy, nor vertical integration. The virtual enterprise in the pharmaceutical industry is often characterized by a focus on project management to coordinate activities and the outsourcing of these activities necessary to achieve the project goal (Cavalla 2003; Boucher and Afsarmanesh 2013; Müller *et al.* 2013).

As manufacturing firms attempt to move up the value chain by offering additional services, service based manufacturing is an increasingly popular concept in literature (Neely 2008; Baines *et al.* 2009; Lay *et al.* 2010; Martinez *et al.* 2010; Wilkinson *et al.* 2009; Baines *et al.* 2009; Vandermerwe and Rada 1988; Smith *et al.* 2014; Zhen 2012) that often appears in context with virtual enterprises (Rodríguez Monroy and Vilana Arto 2010; Ducq *et al.* 2012; Sun *et al.* 2011). In a service based manufacturing scenario, the manufacturer supplier relationship does not follow a traditional customer supplier pattern, as the customer "asks for competencies rather than either only parts or only manufacturing capacity" (Urbani *et al.* 2002). According to Akbarzadeh and Pasek (2008) two different actors can often be distinguished. On the one hand there is the end user, who interacts with the market of finished goods as market supplier and whose core business is the interaction itself. The end user often adds value to the product through design, innovation, marketing, and branding. On the other hand there is the manufacturing service provider, who takes responsibility for the manufacturing response to the market and for customization. As a result, the core business of the manufacturing service provider, is manufacturing itself, which drives its focus on the necessary competencies and, consequently, leads to increased effectiveness. The concept of service based supply of manufacturing services was introduced by Urbani *et al.* (2002), who proposed manufacturing capacity supply as an extension of traditional outsourcing and an enabler for improved responsiveness and effectiveness. Schönsleben (2007) highlights the dynamic character of such partnerships in the area of supply chain management. He describes the transformation of a customer-supplier relationship into a strate-

gic partnership in the supply chain according to the five characteristics quality, costs, delivery, flexibility, and co-operation in the logistics network.

There are also other concepts that do not focus on the transaction type but look at the overall system. One popular concept is to regard the industry as an ecosystem (Moore 1997; Isenmann *et al.* 2008; Isenmann and Hauff 2007) which represents an economic community supported by a foundation of interacting organizations and individuals - the organisms of the business world. The economic community produces goods and services of value to customers. The member organisms also include suppliers, lead producers, competitors, and other stakeholders. In general, the industry ecosystem concept is associated with a better economic and ecologic, due to a more efficient use of energy and materials. As such, the actors co-operate by using each other's waste material, by-products and waste energy and in order to optimize the input of both raw material and energy and simultaneously reduce the output of waste emission (Li and Hao 2011; Chew *et al.* 2009; Maes *et al.* 2011; Geng *et al.* 2007). Over time, they co-evolve their capabilities and roles, and tend to align themselves with the directions set by one or more central companies (Côté and Hall 1995; Ritala *et al.* 2013). Within such an ecosystem, different types of company ecologies evolve. If the relationship between the organizations is co-operative and the strengths are complementary, this is a collaborative network.

2.2 Role and importance of outsourcing

All these modern types of collaborations and partnerships rely on outsourcing activities, i.e. covering of parts of the own value chain or supply chain by partners which are more suited to perform these activities. The main perceived advantages are reduction of costs and better allocation of resources in a project with variable demand, access to specific technology, expertise or skills either not present internally or less expensive/quicker than the internal alternative, greater flexibility, better management or spread of risk and freedom to concentrate on core functions. Jiang and Qureshi (2006) identified expected benefits of outsourcing and sort them into the following five categories: cost reduction, productivity growth, profitability increase, firm's value improvement, and risk control. But outsourcing is not an optimal solution in all cases. It is a trade-off and involves some disadvantages, like loss of control (e.g. of quality and regulatory compliance) (Bath 2003; Linna *et al.* 2008), greater difficulty of co-ordination and management of external collaborations and contracts, less transparency (e.g. problems of evaluating and monitoring sup-

plier performance), time taken to negotiate contracts, difficulties in agreeing on ownership or splitting of intellectual property rights, instability risks in case the external party becomes financially insolvent, merges or is acquired and generally dependent on the supplier.

Due to the broad array of potential engagement options, risk and benefits, there are many variations of outsourcing alternatives and several authors have attempted to develop a framework clarifying the wide spectrum of outsourcing arrangements, and their inherent risks and advantages (Sanders *et al.* 2007; Abdullah and Verner 2012; Sharp *et al.* 2011; Vitasek and Manrodt 2012; Braun *et al.* 2011; Hsiao *et al.* 2010b; Roy and Sivakumar 2012). Shared characteristics among early adopters of outsourcing have been shrinking product lifecycles and the growing need for agility and responsiveness to counterbalance increasing market volatility. As a result, fast moving industries, such as consumer goods manufacturing, like electronics and fashion, were more likely to embrace outsourcing when compared to slow-moving industries, like automotive and machinery. Increasing market volatility calls for new organizational forms enabling agility and responsiveness, which in turn forces firms to define and focus on their core competencies, streamline their operations, and leverage complementary competencies of suppliers to their competitive advantage in effectively managing continuous change (Akbarzadeh and Pasek 2008).

Outsourcing manufacturing is moving away from a purely opportunistic approach, transferring overcapacity to external partners or outsourcing of manufacturing to low-cost countries for the sake of cost reduction, towards a more strategic partnership approach. Han, Porterfield, and Li (2012) analyzed the impact of industry competition on contract manufacturing. This empirical study found that contract manufacturing is positively associated with supplier industry competition and the association is further moderated by focal industry competition and IT investment. One of few studies in this field based on financial metrics is the work of Plambeck and Taylor (2005). They studied profitability and investment in capacity and innovation in outsourcing manufacturing to contract manufacturers and concluded that contract manufacturing improves profitability for the industry as a whole only when companies are in a strong bargaining position vis-à-vis the contract manufacturer.

In the course of their literature review, Jiang and Qureshi (2006) determined that related outsourcing literature can be classified by three criteria: 1) outsourcing determinant, 2) outsourcing process, and 3) outsourcing result. The outsourcing deter-

minant research studies the drivers behind a firm's outsourcing decision, i.e. the "why" issues. Research on outsourcing determinants often refers to the transaction cost economics and the resource based view of the firm to study outsourcing agreements. The interest in the topic comes in waves and is strongly dependent on the status of the industry (i.e. maturity, business cycle, competition, regulation, etc.). The outsourcing process research focuses on outsourcing contract negotiation, partner selection, implementation, control, monitoring, and so on, i.e. the "how" issues. The process oriented research, most frequently concerns itself with outsourcing contract negotiation and partner auditing and monitoring (Jiang and Qureshi 2006; Mayer and Salomon 2006; Contractor *et al.* 2011; Ding *et al.* 2013; MacKerron *et al.* 2014; Zhang *et al.* 2013). Analysis of contract negotiations and bargaining power often uses the game theory model (Lai *et al.* 2009; Kumari *et al.* 2013; Vitasek *et al.* 2013; Leng *et al.* 2014).

The outsourcing result research studies what an outsourcing decision brings to the firm. Several researchers (Jiang and Qureshi 2006; Jiang *et al.* 2006; Hsiao *et al.* 2010a; Kitchee *et al.* 2012) see a gap regarding the third research area, the outsourcing result literature. Within the last decade, most academic studies have focused on understanding outsourcing decision determinants and outsourcing process control (Gilley *et al.* 2004). While contracting out is now broadly understood to be an attractive option, its specific impacts on firms' performance and value, i.e. outsourcing results, have not yet been well confirmed by research. When researchers look to measure the financial impact of outsourcing results, they have usually been forced to rely on managers' estimates rather than tangible metrics and "much of the evidence that we have come across is anecdotal and case study oriented, and often based on non-financial metrics" (Jiang and Qureshi 2006). Jiang and Qureshi (2006) defined three main gaps in the outsourcing research literature: 1) lack of objective metrics for the evaluation of the outsourcing results, 2) lack of research on the relationship between outsourcing implementation and firms' value, and 3) lack of research on the outsourcing contract itself.

2.3 Outsourcing in the pharmaceutical industry

A number of authors analyze and explore outsourcing in various industries and some of these papers cover the pharmaceutical industry. Strategic outsourcing has assumed an increasingly important role in the operations of established as well as emerging pharmaceutical companies (Getz 1997; Lowman *et al.* 2012). Specific advantages and

disadvantages of outsourcing in this industry are explored, amongst others, by Cavalla (2003). Historically, most management attention has been paid to drug discovery and sales and marketing, the outer ends of the supply chain (Booth 1999). Therefore, in the pharmaceutical industry, research in the last few years has focused on R&D contractors and product development (Festel *et al.* 2010). Examples of such research are the work of Arranz and de Arroyabe (2008), which focuses on the choice of partners in the pharmaceutical industry for R&D co-operation, and Festel (2011) on outsourcing of chemical synthesis during the drug discovery phase. Another example is Piachaud's analysis of the outsourcing of R&D by pharmaceutical companies to clinical research organizations which empirically analyzes the perceived advantages and disadvantages pharmaceutical firms have experienced (Piachaud 2002).

Whereas partnering in the drug discovery and development process as well as sales and distribution are well covered by many studies (Henderson and Cockburn 1994; Henderson and Cockburn 1996; Subramaniam and Dugar 2012; Macher and Boerner 2012), the outsourcing of pharmaceutical production is not. Methodologies are often just adopted from the manufacturing industry. Furthermore, research on partner selection, implementation, control and monitoring in the pharmaceutical industry in general and the production process in particular is rare, despite the fact that outsourcing the manufacturing of active ingredients, formulation as well as primary and secondary packaging is growing (Clinkscales and Geimer 2001; Linna *et al.* 2008; Ernst & Young 2010). Van Arnum (2006) estimates that in the US, the total value of commercial pharmaceutical manufacturing of finished dosage forms is 83 billion US-Dollar, of which 8-12 billion US-Dollar is outsourced. Manufacturing is often further differentiated into primary and secondary manufacturing (Shah 2004). The primary manufacturing site is responsible for the production of the active ingredients. This normally involves either several chemical synthesis and separation stages to build up the complex molecules involved, or fermentation and product recovery and purification in the case of biochemical processes. Secondary manufacturing is concerned with taking the active ingredient produced at the primary site and adding excipient inert materials along with further processing and packaging to produce the final products, usually in stock-keeping unit form.

An important area is the outsourcing of the production of active ingredients. Most pharmaceutical products involve primary active ingredient production (often multi-stage chemical synthesis or bioprocess) and secondary (formulation) produc-

tion. Both of these stages are characterized by low manufacturing velocities and are hampered by the need for quality assurance activities at several points (Shah 2004). The oldest concept which has been broadly analyzed in the literature is contract manufacturing, which is considered as one category of outsourcing (Liston *et al.* 2007) and as such is often related to outsourcing topics. Contract manufacturing is regarded as a supply chain arrangement by which a manufacturing firm outsources some of its manufacturing processes to an outside supplier through a contractual agreement (Kim 2003). The pharmaceutical company maintains the ownership of the products while the contract manufacturer supplies labor and skills to manufacture the products. A more sophisticated example is the work of Naerhi and Nordstroem (2005), who analyze the challenges of choosing an appropriate contract manufacturing organization in the bio-pharmaceutical industry during the ramp-up phase for commercial manufacturing. This is a common scenario as the investments for bio-manufacturing facilities are high.

3 Methodology

After explaining why action research based on a single case study was chosen as research method, the details regarding data collection and analysis are described.

3.1 Research method

Action research has the dual goal of solving a problem and contributing to knowledge by participation of the researchers in the problem solving process (Westbrook 1995, Greenwood and Levin 1998). Therefore, action research is an appropriate method for developing a business process in a company (Eden and Huxham 1996, Coughlan and Coughlan 2002). This is achieved through a structured process with the steps 1) data gathering, 2) data feedback and analysis, 3) action planning and implementation as well as 4) evaluation (Susman and Evered 1978; Burns 2000; Coughlan and Coughlan 2002). Following the action research article by Pero and Rossi (2013), the desired outcomes of this research paper are the solution to the immediate problem and the lessons learned, but not to develop a new theory or to validate an existing theory.

Previous work on outsourcing topics has relied mostly on anecdotal evidence from case studies, surveys or other self-reported data to support assertions (Jiang and Qureshi 2006). Consequently, the action research approach in this article is based on a single case study of a globally leading pharmaceutical company in order to obtain in-depth insights

into the subject. As suggested by Yin (2013) case studies are preferred for studying contemporary events where it is not necessary to control behavioural variables. A single case study approach is appropriate, if the aim of the research is to explore a previously unexplored phenomenon (Eisenhardt 1989; Eisenhardt and Graebner 2007; Yin 2013).

3.2 Data collection and analysis

In the action phase, one author was closely involved with the company in developing and customizing a company specific partner selection process including the criteria for the partner selection. The other authors served as sparring partners and supervisors to ensure that a systematic, structured and scientific approach was followed. The whole project was structured in the four phases 1) data gathering, 2) data feedback and analysis, 3) action planning and implementation as well as 4) evaluation.

1) Data gathering: The information was primarily collected through direct interviews, direct observations and involvement in the company's management activities. First, a relationship was established with the senior management of the company. Two of the authors were introduced to key people and, subsequently, embedded in the task force team responsible for the project. Semi-structured interviews (each interview lasted on average one and a half hours) with each of the key informants were performed. The interviews comprised a set of open questions to understand especially the supply chain management activities. Secondary data about the relevant companies, market and competitors were collected through documentary sources, such as annual reports, strategy plans, press releases on company web pages or through other forms of company reports and project documentation. Besides the objective to obtain an in-depth view about the situation, this information was also used to triangulate the data collected.

2) Data feedback and analysis: The relevant data were continuously shared among the people involved in the project and frequently analyzed together in order to define clear objectives and to identify issues and needs as well as further areas for improvements. The confirmation of the results coming from the interviews was made through discussions within the team of authors and with the interview partners after writing down the interviews results. Contacts with contract manufacturers and suppliers

were also established to discuss the results with them. Based on the concepts and trends identified during the literature research, which are described in the theoretical background section, the partner selection process described in the next section of this paper was developed within the task force team based on the interview results. Key statements regarding the partner selection process were extracted from the interview notes and consolidated based on the learnings from the literature review. The result was the description of a partner selection process with 7 steps. The whole process was then validated by all interview partners by making minor adjustments.

3) Action planning and implementation: In cooperation with the involved managers, a plan for the implementation of the new partner selection process was defined. Answers were found to questions, such as, what type of change is required, which support and information are needed, and how the new partner selection process could work. The planned actions were then executed with the assistance of the two authors of this paper, who were members of the task force team.

4) Evaluation: In order to generate generic knowledge on the partner selection process from this specific case, the results were verified and generalized within an evaluation phase by presentation and discussion with a group consisting of experts from four additional pharmaceuti-

cal companies (Eden and Huxham 1996, Greenwood and Levin 1998). Supported by quantitative as well as qualitative data, other perspectives had also been included in this verification process, such as those of outsourcing contractors and manufacturing service providers. The aim of these discussions was to obtain feedback from external experts regarding the partner selection process and to gain first insights whether this process could be also implemented in other pharmaceutical companies. Nevertheless, the aspects of generalizability and implementation in other companies are still open and should be part of further research as described in section 5.3.

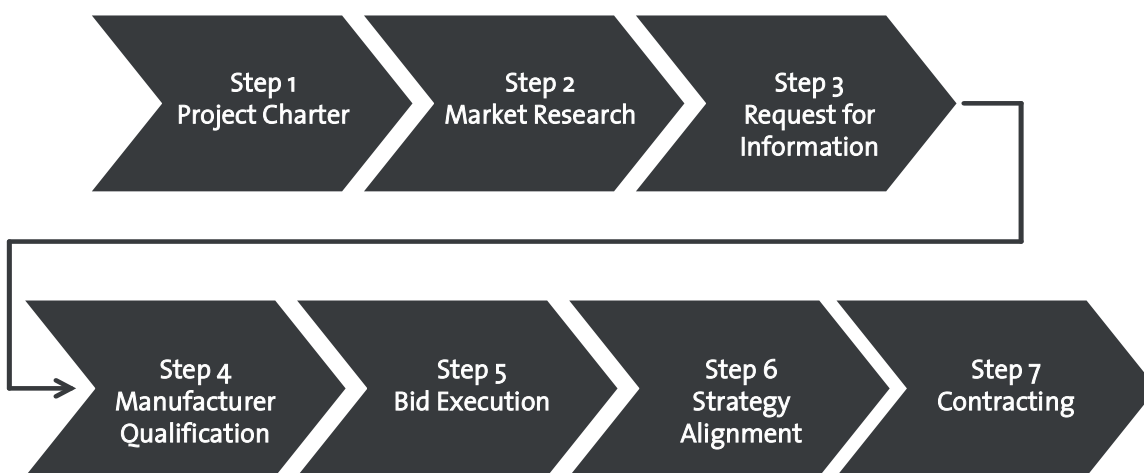
4 Results and discussion

After describing the partner selection process developed within the research presented in this paper the criteria for the partner selection are explained.

4.1 Partner selection process

The importance of a professional partner selection process for pharmaceutical companies in the area of outsourcing manufacturing has been emphasized in the introduction and the theoretical background section. The partner selection process developed during the action research consists of nine consecutive steps and is illustrated in Figure 1. The preceding make-or-buy evaluation will not be further described in this paper and is a dif-

Figure 1 Partner selection process.



ferent field of research.

Step 1: Project Charter

The process starts with the development of the project charter. Either a company specific or a general project management template can be used. One widely used general project management methodology is the PMBOK Guide from the Project Management Institute. The key points of the project charter are the project scope, objective, participants, timeline, roles and responsibilities. Furthermore, the strategic intent of the project has to be specified, including milestones and assumptions. By that time, a preliminary business case including a profitability calculation is developed and internal or external competency screening has been done. The project charter is defined and agreed on by all stakeholders involved in the project.

Step 2: Market Research

A dedicated team is in charge of the search for and identification of potential strategic partners using market intelligence information and tools. Prematurely determining a preferred partner list based on a limited non-holistic approach should be avoided in this phase. It is important in this step to avoid personal preferences or selective interests influencing the selection. This could lead to high hidden costs in the end. If the internal resources are very limited and suitable tools are not available, a market scan can also be done using an independent external partner. The result of this step will be a long list of potential partners for external manufacturing. The phase may be time consuming but will deliver an important basis for decisions at the end.

Step 3: Request for Information

This step starts with the development of a specific request for information (RFI). In addition to the questions related to manufacturing capabilities for pharmaceuticals, the document includes background information about the objectives of the partnership, the RFI process timeline, deadlines and submission instructions, and a confidentiality agreement. In addition to those items, compliance with the code of conduct or a specific supplier code of conduct can already be included in the RFI. Preceding work has shown (Oehmen et al. 2010) that reference to a supplier code of conduct in an early phase of negotiation helps to mitigate risks related to production, for example workplace safety issues around hazardous materials. The dedicated sourcing team is responsible for releasing the RFI

to the potential contract manufacturers identified, communicating and clarifying requirements, acting as the single point of contact for questions, ensuring on-time submissions, and providing feedback. This step is important for the clarification of the needs, as many questions are likely to be asked by the potential partners. It is important that questions arising during the RFI are clarified with all suppliers involved to establish an equal level of information for all participants. Therefore, these information updates during the process should be defined by a change control procedure and proactively managed by the sourcing team. After RFI submissions are collected from potential contract manufacturers, the team reviews them and comes to a shortlist of three to four companies. This selection is again very important and needs to be performed using a comparison matrix agreed with all internal stakeholders. Finally, all participants (selected and excluded) are officially informed about the results and feedback is provided, which is often appreciated and facilitates future RFIs.

Step 4: Manufacturer Qualification

The selected potential partners will then enter into the next phase where they are assessed by the technical assessment team following predefined criteria. The particular categories may be assessed by different experts, but the same expert should assess a particular category for all suppliers included. The final assessment report contains an overall rating for each category. Certain criteria may be defined as minimum requirements. They should receive additional comment from the experts as to whether an existing gap could be closed by additional measures. Ideally, the potential suppliers are shown their assessment and the opportunity to provide feedback is given. After the technical assessment, the different results from the rating as well as the written technical assessment report are reviewed again by the external supply integration team, quality and compliance, logistics, and finance, which complements the assessment by the technical experts with a more holistic view. The result is a priority list based on the existing short list of potential suppliers.

Step 5: Bid Execution

The potential suppliers on the priority list are approached again for a quotation based on detailed technical specifications and realistic project goals resulting from the technical assessment. The bid request also includes binding plans and actions required to mitigate gaps which have been identified during the technical assessment, actions nec-

essary to get aligned with general expectations, as well as actions required to achieve the objectives of the collaboration. After bid receipt and comparison, both technical assessment and quote should be compared and a final decision taken. The preferred partner is then invited for a strategy alignment workshop. Partners not selected should be informed accordingly and placed on hold until the selection process is completed, as several hurdles have to be cleared during the strategic alignment as well as the contract signing phase.

Step 6: Strategy Alignment

A strategy alignment workshop is prepared by both parties and should involve middle and higher management representatives. The objective of this workshop is to determine a common strategy for the future collaboration. Vision and mission, targets, communication, relationship management, innovation strategy, supply chain set-up, escalation channels, available resources, etc. are discussed and defined. A relationship charter, relationship governance as well as agreed transition and integration governance should be the outcome.

Step 7: Contracting

The transition process step covers the time period from the signature of the letter of intent, through the actual project phase to ramp up the collaboration, to the transition of the relationship to a functioning level. During this phase a project team composed of members of both parties work on the technical transfer and the finalization of all needed agreements, like the quality, supply and service level and other specific agreements needed to cover and specify the collaboration. After some months, the letter of intent should be replaced with the final contract. This transition phase focuses on process, product and knowledge transfer and ends ideally with an agreed plan for handover to the final integration step. The transition and integration steps have an overlap phase where the transition team maintains responsibility for the final result while the integration team operates the partnership. This overlap phase could be time-bound through agreements made for a certain number of batches, for example. Both transition and integration phase should be managed by a joint leadership team as well as a joint operation management team. Finally, the term sheet and contract are established, incorporating key contractual terms as well as partnership objectives. Important items here are the focus on common goals and deliverables, contract duration and commitments, information exchange and intellectual property, problem solving approach

and escalation, open book costing and transparency. The time period from partner selection to the end of the contract is followed by an integration and supplier relationship management process.

4.2 Criteria for partner selection

Basic criteria

Basic criteria are the criteria a potential partner has to fulfil as a minimum requirement to qualify for partnerships. Companies formulate their expectations in a statement. An example for basic criteria in the quality and regulatory arena is given by Schönsleben (2007): each partner carries extensive responsibility for end-user satisfaction, and guidelines, structures and processes of the partnership are developed mutually and act as a basis for the first- and second-tier suppliers as well as for the customer relationships and return processes. These basic criteria can be clustered into three categories: 1) quality and compliance criteria, 2) code of conduct criteria and 3) supply chain partnership criteria.

1) **Quality and compliance criteria:** They are quite standardized in this highly regulated industry and often involve widespread industry practices and require full compliance with quality and regulatory requirements, like the International Conference on Harmonization of technical requirements for registration of pharmaceuticals for human use and Good Manufacturing Practice (GMP). The most widespread version of GMP is the one by the World Health Organization which is used by pharmaceutical regulators and the pharmaceutical industry in over one hundred countries worldwide, primarily in the developing world. There are two other popular versions, one by the European Union (EU-GMP) and the other by the Food and Drug Administration in the US, referred to as cGMP.

2) **Code of conduct criteria:** They can be subcategorized into labor conditions, health and safety, environment and ethics (Oehmen et al. 2010). Often, full compliance with domestic laws is required, and for labor conditions international standards are applied such as those of the International Labor Organization of the United Nations. Some of the topics that arise here are child labor, discrimination, bribery and conflict of interest. The protection of patent and other intellectual property rights may be of special importance for strategic partnerships in the pharmaceutical industry. An increasing number of companies have prepared a specific code

of conduct for their suppliers and strategic partners, usually titled supplier code of conduct (Oehmen et al. 2010).

3) Supply chain partnership criteria: A set of qualitative criteria is recommended for the general basic criteria referring to the supply chain partnership. Kim et al. (2010) analyze the critical success factors in supply chain partnerships as discussed in current research. They identify eight factors that fall into the category of enabling criteria: leadership, commitment, coordination, trust, communication, conflict resolution techniques, resources, and performance. Some of them are already covered in the other categories. Other criteria which were of importance were supply chain reliability and business continuity planning, as well as financial liability and stability.

Strategic Criteria

The strategic criteria are company-specific and aligned with the strategy depending on the purpose of the partnership. This study suggests a criteria catalogue using the four categories 1) reach, 2) integration, 3) technology and 4) customer insight. The level of strategic fit will be defined according to these. The criteria mentioned here refer to the partner selection process. For an established strategic supply chain partnership, different criteria have to be applied.

1) Reach: Partners with global, regional or local presence and capabilities in the manufacturing and/or distribution of desired products to desired customers in the world, the region or a particular country. Large pharmaceutical companies can benefit from expanding their global reach, reduced cost, supply chain resilience, and secured sales. The main partner benefit is economy of scale.

2) Integration: Partners with horizontal R&D and production capabilities enabling rapid new product introduction with the capability to perform clinical trials, registration, submission and commercialization of products. Partners with vertical integration and excellent capabilities in a specific supply chain step like manufacturing of active ingredients, compounding, filling, optical inspection or secondary packaging. The main benefits for the pharmaceutical company are in the case of horizontal integration faster time-to-market and increased sales, and in the case of vertical integration reduced cost. Again, the partner benefits from economy of scale

effects.

3) Technology: Partners specialized in readily available manufacturing technologies supporting manufacturing platforms, like liquid par-enteral, solids tableting, transdermal patches or packaging. Partners with specific manufacturing process capabilities like auto injectors, dual chamber technology or other technologies requiring specialization and capital intense investments. Partners specialized in the management and operation of those technologies. Large pharmaceutical companies benefit from supply chain resilience, life cycle management, reduced cost, and avoidance of tied-up or fixed capital. Partners benefit from high volumes of produced units for their specialized technologies and economy of scale effects.

4) Customer insight: Partner with local or regional presence enabling market entry or growth opportunity in a specific market segment, like the branded generics business in emerging countries. As some countries are unique in terms of regulations and market access, local companies could be of strategic help in understanding regional and local specifics both visible and not so visible (for example, some countries in emerging or developing markets do not accept products produced in specific countries). The pharmaceutical company benefits from market entry and the partner from a business model attracting high volumes for specialized technologies and economy of scale.

5 Conclusion

After describing important aspects of implementation, the impact of the partner selection process as well as the limitations and need for further research are explained.

5.1 Implementation of the selection process

Three aspects have to be taken care of and are basic to project management. First is the involvement of all relevant stakeholders. It is a challenge to include all needed stakeholders right from the start while keeping the project team lean and decisive. Secondly, seamless cross-functional collaboration is important. Teams with different interests and views from sourcing, production, compliance, etc. need to talk the same language and work towards the same goal. A culture of openness to compromise and participative leadership will be a great help. But in the end it is also a matter of training. After several projects have been finished,

they should be reviewed and the process and the collaboration continuously improved. The same is true for the third success factor, the clear definition of team responsibilities. As mentioned, the involvement of all stakeholders is required, but duplication of work has to be avoided and decision makers should be experts in their fields and not biased by conflicting interests.

Depending on the process phase, different teams are involved and several tools are used to ensure information access and flow. Besides having the right process in place, the appropriate organizational structure has to be established to properly support these teams realizing the partner selection process. Several of the study participants have confirmed that they are increasing their resources for the selection and management of external partnerships within the supply chain department. Furthermore, the result of restructuring approaches of large pharmaceutical companies has set the supply chain department on the same level as internal manufacturing.

An important basis for successful implementation of the process is to make sure that the appropriate market intelligence tools are in place. Access to information and efficient management is important, especially due to the number of different teams involved in the process steps. Market information is extremely important once the RFI process starts, as by then a pre-selection of partners is made. Looking at the linkages of each single process step with the market intelligence function, it is obvious that without a clearly described process and supporting tools a lot of intangible information will be lost and not be visible to the people involved in the initial scouting phase or to people who need information for any other reason or for some future project. Strategic partnerships are also an important means to control risks. Depending on the choice of partners and the type of partnership established, risks can be avoided, shared or transferred. It is also crucial for the implementation to include risk considerations in the overall decision making process and especially the partner selection process.

5.2 Impact of the partner selection process

The study confirmed that strategic outsourcing requires different partner selection processes and selection criteria compared to opportunistic outsourcing as outsourcing has to fit into the whole corporate strategy taking into account all advantages and disadvantages on a corporate level (e.g. risks for the core business). Partnering is shifting away from being purely a matter of cost reduction towards a more strategic partnership approach where partnering is seen as an opportunity to cre-

ate value for the company.

The short-term impact within the analyzed pharmaceutical company was a significant change in the thinking of the core people. Selecting and establishing strategic partnerships was seen more as a key competence for achieving long-term strategic advantages rather than only achieving short-term cost saving potentials. One concrete aspect was the insight that a long-term relationship enables the parties within a strategic partnership to take more strategic decisions allowing long-term joint investments.

5.3 Limitations and need for further research

The strategic partner selection process for outsourcing of pharmaceutical manufacturing presented in this paper is still rather generic and specific to the pharmaceutical company analyzed and described in the case study. An important question is whether the partner selection process from this specific case can be generalized in the sense that the partner selection process can be used and implemented as best practice process also in other pharmaceutical companies. The possibility of generalization is expected and future research involving other large pharmaceutical companies could confirm that this process can be also adapted to other companies.

The selection process, including the criteria for partner selection, is currently implemented in the analyzed pharmaceutical company, but will need to be adapted to unforeseen aspects. As this process is newly developed, long-term results of its application cannot yet be provided and are a matter for future research. Another topic of future research would be in-depth analysis of the criteria applied in the process. If the research gap as regards measuring financial impact on outsourcing results could be closed, these results would complement and validate the partner selection process.

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Practitioner's Section

Correlation between Sales and Profit Development and Ownership Type in the Chinese Chemical Industry

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This paper examines the correlation between ownership type of chemical companies in China and the development of their sales and profit in the period from 2006 to 2012. Data from China's statistical yearbook for the industry segment "Manufacture of Raw Chemical Materials and Chemical Products" was used, which covers all larger companies with annual sales above about 20 million RMB of sales (more than 20,000 companies in the segment). The results show a strong correlation between ownership type and growth in profit and sales. Private domestic companies perform best, achieving sales and profit growth rates that are substantially above the industry average. In contrast, the performance of foreign-owned chemical companies is slightly below industry average while the results of state-owned chemical enterprises are substantially below industry average. Possible reasons for the difference in performance are given, and consequences for the different ownership types are discussed.

1 Introduction

One of the main differences between the chemical industry in China and in Western countries is the existence of three distinct major types of ownership: private-owned, foreign-owned and state-owned. The ownership type affects many relevant properties such as company goals, amount of local control, technical knowledge, management style and others. As a consequence, the ownership type may have an impact on the performance of chemical companies in China.

Several studies have aimed at identifying the correlation between ownership type and company performance in China, though none of these studies looked specifically at the chemical industry. For example, Wei et al. (2002) found that a higher remaining share of state ownership in newly privatized companies lowered the performance of these companies. In contrast, Sun et al. (2002) found a positive relationship between government ownership and firm performance in companies listed in Chinese stock markets, though the authors admit that this may be due to monopoly rents derived from their government ownership. The results of

Xiao et al. (2000) point in a similar direction. They found that legal person shares have positive effects on firm performance while state ownership has a negative impact - however, they state that this is true only in the competitive electronics industry and not in less competitive industries such as utilities. Finally, Wei et al. (2005) found that state ownership is negatively related to firm value while foreign ownership is positively related.

The objective of the research outlined in this paper was to examine the correlation between ownership type and the development of company performance in the Chinese chemical industry as this is the main area of interest and expertise of the author. Ideally, such research would focus on individual chemical companies that changed their ownership type while leaving other relevant parameters unchanged. However, this would result in a very small sample size, and even for these samples, gathering performance data would likely be impossible. Instead, the research was based on the data given in the Chinese statistical yearbook. This data includes the aggregated sales and profits for each of the three main ownership types within the period of 2006-2012, split by industry segment. For the

period of 2006–2011, the number of employees per ownership segment is also available, allowing some additional analyses such as sales and profit per employee.

In total, the sample thus covers 22,600 chemical companies with total combined sales of 6,010 billion RMB, total combined profits of 443 billion RMB and a total number of employees of 455,000 (data for 2011).

2 Analysis Details

The data used for the analysis was taken from the Section “Industry” of the China Statistical Yearbook, editions 2007–2013, which contain data for the years from 2006–2012. All data was taken without any corrections as given by the National Bureau of Statistics of China.

Worksheets utilized were “Main Indicators of Industrial Enterprises above Designated Size by Industrial Sector”, “Main Indicators of State-owned and State-holding Industrial Enterprises by Industrial Sector”, “Main Indicators of Private Industrial Enterprises by Industrial Sector”, and “Main Indicators of Industrial Enterprises with Hong Kong, Macao, Taiwan and Foreign Funds by Industrial Sector”.

In each worksheet, data for the industry segment “Manufacture of Raw Chemical Materials and Chemical Products” (as defined in China’s national Standard of Industrial Classification, GB/T 4754-2011) was used as a proxy for the chemical industry. This segment includes the sub segments of basic chemicals manufacturing, fertilizer manufacturing, pesticide manufacturing, coatings manufacturing, plastics manufacturing, specialty chemicals manufacturing, explosives manufacturing and

manufacturing of household chemicals. It does not include manufacturing of pharmaceuticals, chemical fibers, tires, plastic parts and non-metallic mineral products such as gypsum.

Data used from these worksheets to characterize the chemical industry were Number of Enterprises, Revenue from Principal Business, Total Profits, and Number of Employees (see Tab. 1 for the sample data for selected years). All data referred to mainland China only. Particularly in the case of foreign-owned enterprises, this may lead to some distortion as parts of their value creation may have been done outside of China. For example, foreign-based researchers of foreign-owned companies may develop products which are also sold in China – however, they will not be counted among the Chinese employees of the company despite their participation in the value creation process.

According to the China Statistics Yearbook, the scope of industrial statistics were all industrial enterprises with mainland China revenue from principal business of over 5 million RMB from 1998 to 2010. Since 2011, the scope was adjusted to all industrial enterprises with mainland China revenue from principal business above 20 million RMB. This adjustment needs to be considered in the discussion of the results. For example, the higher threshold starting from the year 2011 may have led to lower figures for the years 2011 and 2012 than for the previous year. However, in the chemical industry 20 million RMB (about 2.4 million Euro at 2014 exchange rates) is still a low sales threshold in the chemical industry, thus the distortions are likely to be only small. In general, the size threshold is most likely to lead to an underrepresentation of the share of private enterprises as these are on average by far the smallest companies of the

Table 1 Sample data for 2006 and 2011.

Ownership	Number of Firms		Revenue (bn RMB)		Profit (bn RMB)		Number of Employees	
	2006	2011	2006	2011	2006	2011	2006	2011
SOE	1,551	1,124	615	1,167	28	56	1,070,000	970,000
Private	10,375	12,089	454	1,893	24	142	1,050,000	1,590,000
Foreign	3,295	3,537	548	1,560	41	137	480,000	750,000
Other	5,494	5,850	415	1,390	21	108	980,000	1,240,000
Total	20,715	22,600	2,032	6,010	114	443	3,580,000	4,550,000

three ownership types. However, the results shown below qualitatively hold true even if such an under-representation indeed occurred.

As indicated by the worksheets listed above, the statistical yearbook reports data for the whole industry segment as well as for three different ownership types.

State-owned and state-holding enterprises are state-owned enterprises plus state-holding enterprises. State-owned Enterprises are non-corporation economic units where the entire assets are owned by the State. State-holding enterprises are a sub-classification of enterprises with mixed ownership, referring to enterprises where the percentage of state assets (or shares by the state) is larger than any other single shareholder of the same enterprise.

Private enterprises are profit-making economic units invested and established by natural persons, or controlled by natural persons using employed labor. Included in this category are private limited liability corporations, private limited share-holding corporations and private partnership enterprises.

Foreign-owned companies are companies with at least a 25% share of ownership from outside mainland China.

The ownership share not accounted by any of these three types is still fairly large, accounting for about 20-25% of total segment sales. However, it is not split up further. The vast majority of this segment (more than 80%) is accounted for by limited liability corporations with 2-50 domestic investors. As such, this company type is most closely related to private companies as the segment is neither state- nor foreign-owned, and presumably driven

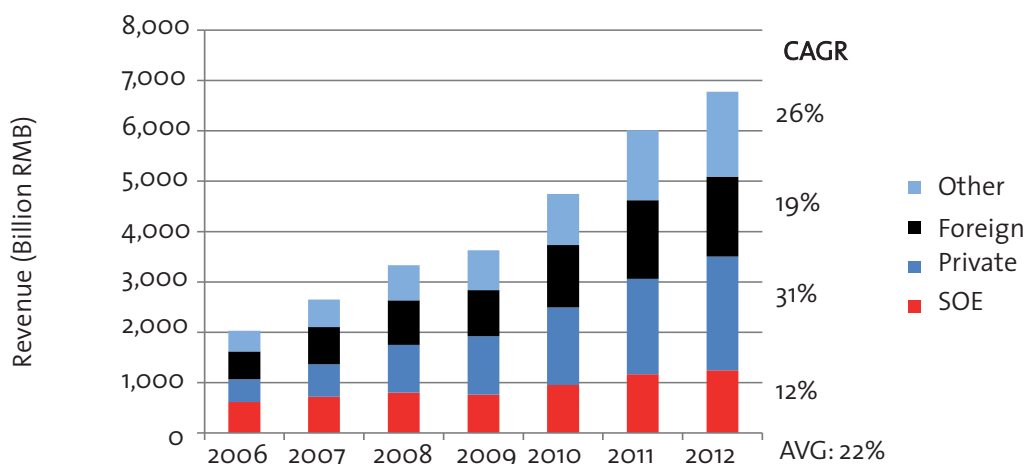
primarily by profit motives. An indication of this fact is that the results for this “Other” segment of ownership are similar to those of the segment of private ownership. However, due to the mixed nature of the “Other” segment, the results for the segment are not discussed.

Unfortunately no complete and consistent data was available for the period before 2006, and for 2012, no data on the number of employees was available. This limited the observation period analyzed.

While using this data allows detecting correlations between economic parameters and ownership type over the course of the observation period, it also has its own risks and thus requires careful interpretation of the initial results. For example, state-owned enterprises may be concentrated in specific sub segments of the chemical industry which are characterized by a performance development that is different from the overall chemical industry. In addition, the average company size is correlated to the ownership type, complicating the identification of causation.

In addition to using the data from the statistical yearbook, a number of open interviews with participants, primarily managers of state-owned, private domestic and foreign-owned companies, in the chemical industry in China have been conducted. The information obtained in these interviews formed an important part of the evaluation of performance differences by ownership type.

Figure 1 Revenue of chemical companies in China by ownership type.



3 Results

3.1 Revenue Development

Revenues of the chemical industry in China more than tripled between 2006 and 2012 (Fig. 1). Domestic privately owned chemical companies were the key driver of this growth. They increased their share of revenue from 22% to 33% percent, a fivefold increase in absolute terms. During the same period, SOEs only about doubled their sales. The compound annual growth rate (CAGR) of private enterprises' revenue thus was much higher (31%) than the CAGR of the total chemical industry sales (22%). Revenue growth of state-owned enterprises was substantially below market average with a CAGR of only 12%. The CAGR of foreign-owned companies was slightly below overall market growth with 19%.

In order to assess productivity trends by ownership type, sales per employee were calculated as well. The results (Tab. 2) show that all chemical companies independent of their ownership type strongly increased their sales per employee, with an average annual growth rate of 18% across all types. Those ownership types with higher sales per employee at the beginning of the observation period (in particular, foreign companies, but also to some extent SOEs) showed slower growth in sales per employee during the observation period.

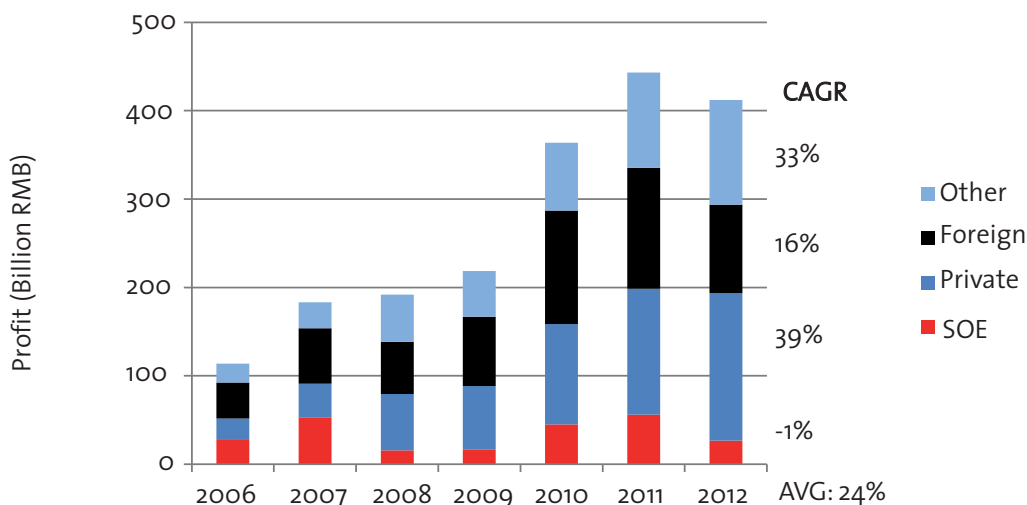
3.2 Profit Development

Total profits of the chemical industry in China increased approximately fourfold between 2006 and 2012. This was a faster growth than the sales growth, with a CAGR of 24% compared to only 22%

Table 2 Revenue per employee by ownership type.

Ownership	Revenue per employee (1000 RMB)						CAGR 2006 - 11
	2006	2007	2008	2009	2010	2011	
SOE	577	719	786	951	758	1,209	16%
Private	432	535	619	885	718	1,189	22%
Foreign	1,139	1,317	1,388	1,637	1,407	2,083	13%
Other	423	526	630	814	698	1,119	21%
Average	568	696	775	1,001	824	1,321	18%

Figure 2 Profit of chemical companies in China by ownership type.



for sales. Similar to the situation regarding sales development, private companies were the key drivers for the growth in profit. They approximately doubled their share of profit from about 20% to 40%, both at the expense of SOEs, whose share of profits dropped from about 25% to about 7%, and of foreign companies, whose share dropped from about 36% to about 24%. In terms of annual profit growth, the difference between different ownership types is also very clear. While profit of private companies grew at a CAGR of 39% (15% higher than market average), the profit growth of foreign companies was substantially below market average (CAGR of 16% compared to a CAGR of 24% for the whole industry). SOEs even had a minor drop in profits in absolute terms, though this may have been due to some specific events in 2012, as SOE profits in 2012 were only about half the level of the

previous year.

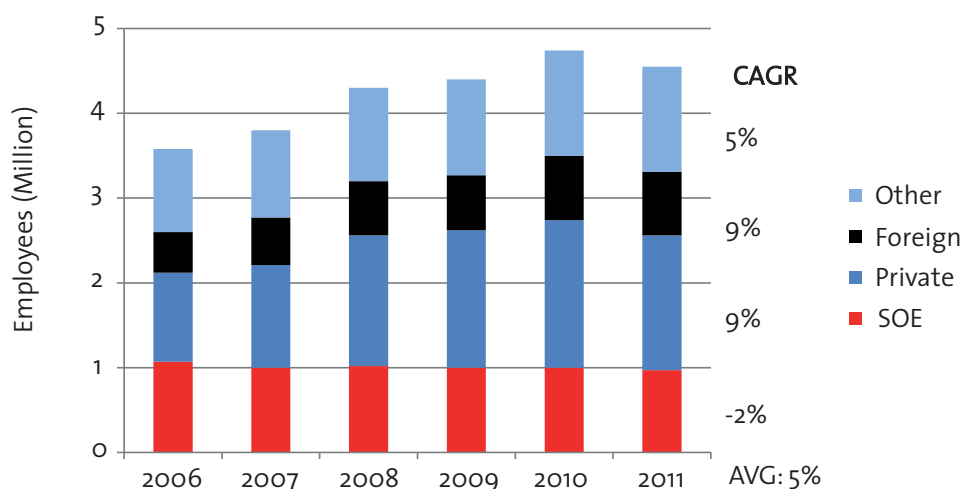
Profits per employee rose strongly for all ownership types of chemical companies. However, this growth was much lower for foreign companies and SOEs than for private companies. As a consequence, private chemical companies by 2011 achieved substantially higher profits per employee than SOEs despite a lower starting point at the beginning of the observation period. Private companies also reduced the relative gap to foreign companies, though in 2011 profit per employee was still only about half the level of that of foreign companies.

In fact, private chemical companies obtained substantially higher profits per employee in 2011 than SOEs even though they were still slightly lagging behind them in 2006. The gap to foreign companies also decreased substantially, being reduced from a factor of four to a factor two within the

Table 3 Profit per employee by ownership type.

Ownership	Profit per employee (1000 RMB)						CAGR
	2006	2007	2008	2009	2010	2011	
SOE	27	53	15	45	21	58	17%
Private	22	31	42	65	45	90	32%
Foreign	85	112	93	170	120	182	17%
Other	22	29	48	62	42	87	32%
Average	32	48	45	77	50	97	25%

Figure 3 Employment development in the Chinese chemical industry.



observation period.

3.3 Employment Development

Employment in the chemical industry rose by about 27% in the period from 2006 to 2011. This is a substantial increase, but it is small compared to the increase in sales (+196%).

Employment by SOEs slightly declined in absolute terms and more strongly in relative terms (from about 30% to about 21% of all employees) but correspondingly rose for all other ownership types, particularly for private companies (+6% of relative share of employees). The percentage of employees working for foreign companies increased by about 3% despite the decreasing sales share of foreign companies

3.4 Other Results

Among all ownership types, SOEs are by far the biggest companies by sales, with the average chemical SOE reaching annual sales of about 1000 million RMB in 2011. Foreign companies are less than half this size (average sales 440 Million RMB) and private companies are again much smaller (average sales 157 Million RMB). Sales per company grew by more than 20% per year for all companies, though growth was fastest for private companies. The number of SOEs shrank substantially during this period (from 1,551 to 1,124 units), which had the consequence of sales per SOE growing at a higher rate than total SOE sales.

Profitability, if defined as total profits divided by revenue, was highest for foreign enterprises, reaching 8.7% in 2011. However, private companies showed the strongest increase in profitability during the observation period and reached 7.5% in 2011, not too far below the foreign companies. State-owned chemical enterprises showed the lowest profitability as well as the lowest growth rate of profitability.

4 Discussion

Focusing on the trends noted during the observation period, the two most interesting results are the much higher growth of domestic chemical companies compared to foreign companies, and the much higher growth of domestic chemical companies compared to SOEs. It is assumed that there is indeed causation and not just a correlation between ownership type and growth in the given circumstances, the rationale for which will be discussed below.

However, another possible explanation is that the lower average size of the private companies is

the main reason for their higher revenue growth. Indeed a smaller company is likely to have a higher growth potential than a larger company already commanding a large market share in its segment, and company size is a well-recognized factor influencing company growth. This explanation cannot be rejected as the data does not allow a differentiation between ownership type and company size. However, the growth difference between private and state-owned entities is so large that it is unlikely that different average company size is the only reason.

Therefore below the higher growth of private domestic companies compared to state-owned and foreign-owned chemical companies in China will be discussed based on the assumption that the ownership type does have an impact on sales growth under the conditions examined.

4.1 Higher growth of domestic private companies compared to foreign chemical companies

Anecdotally, the higher growth of domestic chemical companies compared to foreign companies in China has been mentioned by many industry observers and participants. The data analyzed in this research shows that this phenomenon is real. However, there is uncertainty about the reason behind the faster growth of domestic companies. A number of explanations have been brought forward by consultancies and managers of chemical companies, and will be discussed below. The hypotheses include

- Preference of Chinese customers for low-cost products
- Increasing capability of Chinese companies to produce higher-quality products
- Specific advantages of local companies based on their local ownership, e.g., better access to local raw materials, government preference to buy from local companies
- Better local adaptation of domestic companies, e.g., regarding product requirements, ways of promoting sales, selecting sales channels, etc.
- Greater flexibility of domestic companies
- Greater focus of foreign companies on profits compared to revenue focus of domestic companies (particularly SOEs)
- Higher willingness to invest in the Chinese chemical market

Low-cost preference: In many Chinese markets end consumers have a stronger preference for low-cost products (and usually corresponding lower quality) than in Western markets. This applies to consumer goods such as shoes and consumer elec-

tronics as well as to cars and individual materials used in construction (e.g., water pipes, coatings, etc.), all of which include materials produced by the chemical industry. Producers of low-cost products mainly choose their chemical raw materials based on price while largely ignoring quality differences. This favors domestic chemicals producers who have a larger portfolio of low-end products and lower production costs. In contrast, foreign-owned companies are often unable to compete in the very low-end chemical segments due to higher production and overhead costs as well as a reluctance to use their established brand names for low-quality materials. However, as a stand-alone explanation, this low-cost preference in the Chinese market is insufficient to explain the faster growth of private domestic chemical companies. Undoubtedly the same low-cost preference existed in China at the start of the observation period. If anything, it has probably weakened somewhat as some consumer segments got wealthier and thus got more willing to pay for higher-quality goods.

Improved local products: In the recent past, China's chemical companies have substantially increased the quality level and the variety of their products. In some areas, the last 10 years have seen a shift from distinctly substandard locally produced chemicals to some which are highly competitive. For example, the isocyanate producer Wanhua now reaches the same quality level as its global competitors such as BASF and Bayer. The rapid improvement of Chinese chemical materials has partly been enabled by former employees of foreign companies joining local firms and utilizing their experience. For example, Tianhe, a Chinese producer of lubricants, expanded into fluorotelomers through the hiring of some former DuPont experts and now is one of the leading global players in fluorotelomers. Generally, however, the gains in sales for domestic companies are most visible in relatively mature segments, where chemical substances have been fairly unchanged in the last 10 years. This gave domestic companies the time to catch up with the foreign competition. Most industry participants agree that the technology gap between foreign and domestic chemical companies is indeed shrinking, and that this is a major factor in explaining the faster growth of local chemicals producers.

Specific advantages of local companies: In some chemical segments, multinational companies may have direct or indirect disadvantages due to government regulation and lack of access to local raw materials. For example, participation in the booming segment of coal conversion to chemicals requires access to China's coal at low prices, which is not given to foreign companies. In petrochemicals, for-

foreign companies are restricted to joint ventures without majority ownership – it is likely that this also creates some disadvantages in those steps in the chemical value chain that are directly based on output from the petrochemical industry. Similarly, the Chinese government prefers local buyers over foreign companies. The various stimulus programs of the government, which focus heavily on infrastructure investment, thus favor domestic producers of, e.g., steel coatings, construction chemicals and transportation equipment. This preference may even be stronger on the provincial level, with individual provincial governments preferring the suppliers located in their own province. However, among managers in the Chinese chemical industry, the importance of such specific advantages is generally regarded to be relatively low.

Better local adaptation: As foreign companies are still managed from outside of China, they do not always have the same level of local market understanding as domestic chemical companies. For example, for German producers of chemicals it is still sometimes difficult to understand the local preference for lower prices over higher quality. As a consequence, chemical products produced by German companies tend to be somewhat over-specified – the quality is higher than required by local customers. Of course, local companies also tend to have a better understanding of how to market their chemicals, how to deal with distributors, how to deal with local competitors etc. However, this aspect of better local knowledge and adaptation is likely to have decreased in importance in the recent past as foreign companies have already been in China for some time, and increasingly rely on local staff even on more senior levels.

Greater flexibility: Local chemical companies tend to be less rigid with regard to their products, their target markets etc. For example, several Chinese urea producers reacted to the existing overcapacity by moving towards fine chemicals. Other domestic chemical companies even engaged heavily in businesses outside of chemicals, in particular, in real estate and in finance. They are generally also faster to expand production once local opportunities are spotted. For foreign companies, both the limited local autonomy and the stronger belief in a long-term company strategy make such rapid shifts in business focus less likely.

Focus on sales volume rather than on profit: Foreign companies focus strongly on profitability in their investments, for example, when investing in additional production capacity or in acquiring another company. This may limit their sales to highly profitable segments. Indeed, anecdotal evidence suggests that profitability requirements are lower at private domestic chemical companies. Howev-

er, as the data analysis shows, profits per employee have increased much faster for domestic companies than for foreign companies. In 2006 employee productivity of private companies (as measured by revenue per employee) was only 38% of that of foreign companies while at the end of the observation period in 2011, they already reached 57% of the productivity of foreign companies. This seems plausible as productivity gains are most easily achieved if the starting productivity is low. The adaptation of common practices would be expected to lead to a gradual convergence of productivity, particularly in the case of extreme productivity differences at the starting point. In any case, there is no trend towards a further lowering of profitability requirements by local private companies, making this an unlikely reason for the recent higher sales growth of local companies.

Higher willingness to invest in the Chinese chemical market: Anecdotal evidence suggests that private chemical companies in China reinvest a larger share of their profit into their existing business than foreign companies. This is plausible as China still only offers a limited choice of investment options to its citizens, and in addition, repatriation of profits is not an option for local companies. However, additional research is necessary to determine whether this is an important factor in explaining the faster growth of local companies.

Of the aspects discussed, our judgment suggests the improved quality of domestic chemical products to be almost certainly a key reason for the faster growth of local chemicals producers. While foreign chemical companies may also have somewhat improved the quality of their products, the potential was much more limited due to the high starting level of quality. The improved product quality is particularly relevant for the growing mid-level market segment in China. While in the past there was a vast gap in quality between high-end and low-end products, recently the level in between becomes more and more important. On the demand side, China's growing urban middle classes have the means to require somewhat higher quality than before without already asking for high-end products. On the supply side, both foreign and domestic companies target this market. The foreign companies do this by localizing their value chains to lower their costs, and by adapting their existing high-end products to slightly lower local standards. Local producers already have a cost advantage and increasingly raise the quality level of their products in accordance with these mid-market requirements. Chemicals producers are either directly or indirectly – as raw materials suppliers – affected by these developments.

It should also be noted that the data in the sta-

tistical yearbook does not reflect any changes in the underlying companies (e.g., companies exiting the data pool due to lower sales). While this may have an impact on the results which cannot be reflected in the analysis, this effect is assumed to be small compared to the effects described above.

4.2 Higher growth of domestic private companies compared to SOEs

There are three most likely reasons for the low growth of SOEs compared to private companies. Chemical SOEs are primarily active in mature chemical segments with lower growth potential, such as the production of ammonia, sulfuric acid, PVC or other commodity chemicals. These sub segments of the Chinese chemical market have lower growth rates than the whole market, similar to the growth difference between basic and specialty chemicals in Western countries.

Secondly, SOEs are less flexible in quickly expanding in growth areas and attractive market niches than private companies. This is partly due to their larger size, but also due to the more bureaucratic nature of their company structure and the larger number of people involved in the process of taking business decisions.

Thirdly, SOEs may not regard rapid sales growth as their main objective. In fact, political pressure to increase sales and particularly profits so far has been very limited (e.g., via a requirement to pay dividends to the state owners), though there are indications that this may be changing in the future. SOEs have a role in providing employment, and many loss-making units are under substantial pressure not to reduce their workforce. This may also explain the limited growth that chemical SOEs show in productivity per employee. To some extent, the role of SOEs is the administration and utilization of existing chemical assets rather than the maximization of sales via rapid adoption to changing market needs.

5 Outlook

The analysis suggests that private companies have the highest growth and profit rates in the Chinese chemical industry in the recent past. They substantially increased their share of sales while at the same time increasing their share of profits to an even larger extent. Judging from the ongoing changes in the later years of the observation period, this development is not over yet. Private chemical companies are likely to increase their sales share even further in the next few years. The gap between the product quality of foreign and domestic companies still exists, giving private chemical compa-

nies future potential for catching up. As the chemical industry is a relatively mature industry, it will be hard for foreign companies to compensate for the upgrading of local products via new, more advanced products.

In contrast, SOEs have been very much on the defensive. Their growth was significantly below market growth, and consequently their overall market share and their importance in China's chemical industry decreased. This may be aligned with a deliberate government policy of giving the market a greater role in the economy. However, it still leaves open the question of the future of the chemical SOEs, with the possible exception of the dominant petrochemical companies such as Sinopec and PetroChina. These big SOEs have strategic roles in securing key raw materials for China and may thus receive long-term government support more easily despite their low profitability. However, smaller SOEs may have to accept the shrinking role as providers of employment and thus social stability rather than as profit-driven enterprises, unless the government increases its efforts to maintain their relevance.

For foreign companies, the analysis may seem somewhat disillusioning. An annual sales growth of 19% in the period from 2006 to 2012 certainly sounds impressive from the perspective of stagnant Western markets, and it explains the strong focus of foreign chemical companies on China. However, compared to an average annual market growth of 22% during the same period, the achievements of foreign players are much less impressive. This development is most likely the consequence of a shrinking technology and knowledge gap between foreign and domestic companies. Given the rapid advances of local companies within the relatively short observation period, maintaining a high market share in China will be a huge challenge to foreign chemical companies. As a consequence, foreign companies may have to adapt to their shrinking technological superiority over the Chinese competitors, and adapt their activities accordingly – for example, by developing more localized products and by focusing more on cost competitiveness. In the long run, competition between foreign and domestic chemical companies in China will presumably be one between comparable players, much like competition between, e.g., German and US chemical companies in the US market.

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Practitioner's Section

Emerging trends in the Industrial Greases Market

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Grease, as defined by the American Society for Testing and Materials (ASTM), is “a solid to semi-fluid product of a dispersion of a thickening agent in a liquid lubricant” (ASTM 1978). The production process as well as the overall technology used to produce industrial greases is quite advanced although the structure of industrial greases is very complex as they are composed of multiple semi-solid or solid substances whereas their final structure stays quite sticky.

The article identifies the emerging opportunities for industrial greases and existing drawbacks and challenges that the market participants are aiming to address. The key legislative and environmental factors affecting the industrial greases market are evaluated. The article further focusses on identifying the growth opportunities for bio-based materials in the industrial greases market.

1 Introduction

Industrial greases are one of the most important fluids extensively used by a large variety of industry branches. Their superior properties, durability as well as availability are highly appreciated by professionals. Since many years, different types of greases are employed to protect companies' equipment and machinery. Therefore, it is interesting to analyze the changes as well as future market opportunities for a market that is on the one side continuously developing and is on the other side at a mature stage. Market maturity is monitored especially in the well-developed regions such as North America and Europe. In both regions, it is observed that the average consumption level persisted at a relatively constant level, with a tendency to decrease year-by-year due to shifting of manufacturing base to developing countries such as BRIC and ASEAN countries.

Industrial greases, not yet considered as a highly performing component, are showing a systematic growth. Especially environment compliant vegetable oils such as rapeseed and soybean oils are popular in the global market. Increasing popularity of bio-based materials is mainly driven by environment-oriented regulations. Additionally, it is supported by technological improvements, distinctive for industrial greases. Innovative solutions

attract the interest of new industry sectors that look for the best performing products which are not harmful to the environment. Technologies used for greases are already advanced; nevertheless, bio-greases are still not good enough to compete with mineral or synthetic products.

2 Industrial Greases

2.1 Composition of Industrial Greases

Grease typically consists of three main components that include base oil, thickener and additives (Fig. 1). Base oil is considered as a fundamental grease component. In most greases sold today, refined paraffinic and/or naphthenic petroleum oils are utilized. However, an extensive range of synthetic oils or synthetic fluids is also employed. Synthetic oils that are typically based on poly-alpha-olefins (PAOs), esters, poly-alkylene-glycols (PAG) and silicones are being chosen because of the specific properties they contribute to the industrial greases. For example, adding synthetic oils leads to a reduction or an increase of the operating temperature range. Additionally, these oils offer a good combination of performance characteristics and price. Moreover, the base oil used in grease production determines the type of industrial grease for end users. In general, three main groups of greas-

es exist in the worldwide market (Fig. 2), i.e. mineral oil-based greases, synthetic and semi-synthetic oil-based greases as well as environmentally-friendly greases.

Another crucial component used in greases is thickening agents, also called thickeners. Thickening agent can be a soap type or non-soap type. By adding it to a lubricating mixture, it increases its viscosity without substantially modifying its other properties such as lubricity. So, in general, thickener is a substance that, together with a fluid component, provides the solid or semi-fluid structure to grease. In total, there are many types of thickeners extensively used in the market of greases (Fig. 3). Additionally, from a technological perspective, grease can contain more than one thickening agent. Typically, such mixed and complex thickener-type greases are made of a combination of conventional lithium soap and a low molecular-weight organic acid used as complexing agent.

To sum up, one can observe that the most extensively used greases consists of salts of a fatty acid (soap) emulsified with mineral or synthetic base oil. As everybody who had the chance to work with greases knows that the most distinct feature of greases is their color and high initial viscosity, the type of thickener is normally the first decision making factor regarding the application. However, apart from base oil and thickener, the industrial grease

has in its composition a third equally or even more important component. These are performance enhancing additives responsible for more individual and customized grease properties. These additives typically constitute up to 10% of the total grease weight, whereas the base oil can even account for 90% and thickening agents between 5% and 20%. Moreover, additives and the formulation behind additives are often kept confidential, protected by a number of patents. Additives play several critical roles in greases. They are able to enhance the existing desirable properties, suppress undesirable properties, and impart completely new ones. For instance, additives can improve the tolerance for extreme temperatures, pressure and even speed. So it is not surprising that these 10% of the grease weight distinguish one manufacturer from another and make one grease not compatible with other types.

Apart from these fundamental components, boundary lubricants such as molybdenum disulfide or graphite that reduces the friction can be suspended in the grease. These substances can suffer damages without adverse chemical reactions affecting metal surfaces during heavy loading and slow speeds.

Figure 1 Industrial Greases compositions (Source: Frost & Sullivan 2014).

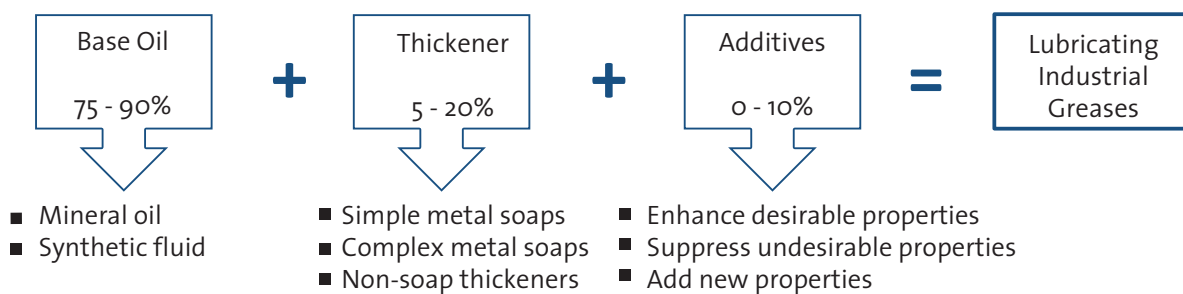
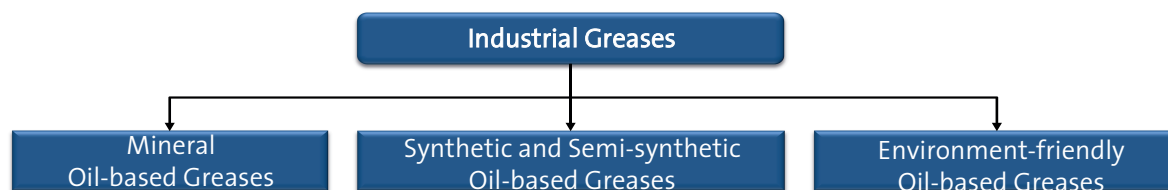


Figure 2 Industrial Greases types depend on the base oil used (Source: Frost & Sullivan, 2014).



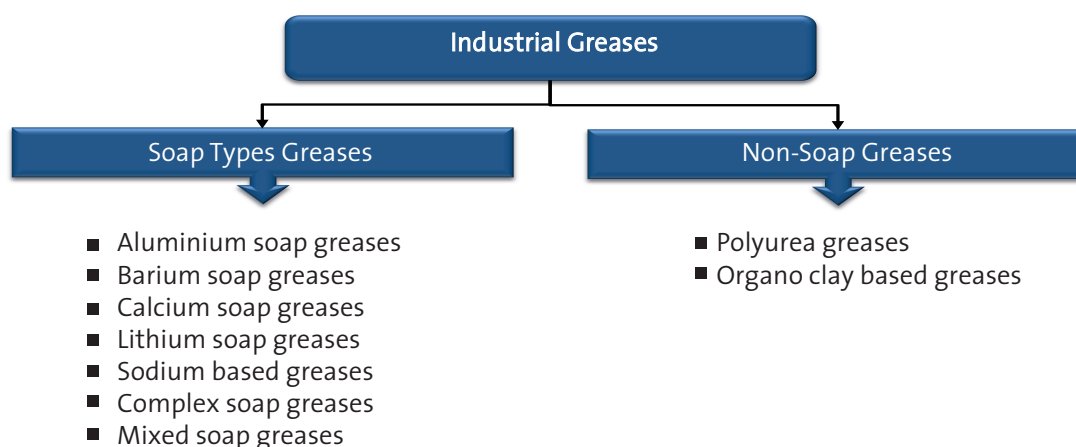
2.2 Functions of Industrial Greases

So, what is the main role of greases? Why is grease so important for machinery? To answer this, one should understand the purpose behind designing industrial greases. In general, industrial greases' main purpose is to minimize friction and wear between moving surfaces. A large number of greases currently available in the market are used in various rolling element bearings. Lower quantities are used in plain bearings, gearboxes and on open gears. Normally, grease for a given industrial application is expected to provide adequate lubrication to reduce friction and to prevent harmful wear of bearing components. Simultaneously, it protects surfaces in machinery against corrosion and acts as a seal that prevents access of dirt, moisture and water. Additionally, grease resists leakage, dripping or undesirable loss from the lubricated surfaces as well as intolerable change in structure or consistency in the bearing especially during prolonged service. Nowadays, industrial greases have suitable physical characteristics adjusted to their application area. They are compatible with seals and other types of materials of construction in the lubricated portion of the mechanism to maximize the comfort of working and the overall performance. Advanced industrial grease tolerates even certain degree of contamination, for instance moisture, without loss of its characteristics. Unfortunately or fortunately, depending on the point of view, there is no all-purpose grease. However, this increases the product variety and improves the competition between manufacturers. Otherwise there would be only one type of grease applicable everywhere. Isn't it a too idealistic perspective?

Maybe, but despite large investments to design the most innovative and the best performing multi-purpose grease, modern premium quality multi-purpose grease are able to meet between 70% and 75% of all applications where grease lubrication is required. For the remaining 25% to 30%, many different and often highly specialized types of grease are necessary. Does it mean that key manufacturers were not able to develop grease applicable for 100% of all applications? As it was mentioned at the beginning of this article, industrial greases are technologically quite interesting and at the same time quite challenging. Moreover, requirements of different industries vary quite significantly.

When industrial grease is used, the base oils, whether it is mineral, synthetic or vegetable oil, the grease is gradually degraded by temperature and pressure in the work piece that is being lubricated. This degrade process will continue until the oil becomes carbonized, unless fresh lubricating grease is applied periodically. As the base oil oxidizes in service, it becomes a contaminant and mixes with the collapsing and degrading base to become so-called "used grease". Typically it is extruded regularly as fresh industrial grease is added to the bearing or work piece. However, sometimes synthetic greases made of synthetic fluid rather than petroleum are required. Even though synthetic greases are affected in service in a similar way, they are characterized by high and/or low temperature capabilities and significantly longer service life. The extent of these capabilities strongly depends on the type of synthetic base oil, thickener type and enhancing performance additive formulation.

Figure 3 Industrial greases types depend on the thickening agent (Source: Frost & Sullivan 2014).



2.3 Market Overview

As greases are available in the market since 19th century, the market for industrial greases is quite old and mature. However, technological innovations and improvements are expected to boost market growth. For instance, Europe and North America are characterized by long-term experience and an extensive knowledge in this field. However, the most rapid growth at the moment is observed in emerging countries such as India, China and Brazil. It is crucial to mention that from the global perspective, the industrial grease market is highly competitive and dominated by key multinational corporations typically related to crude oil production.

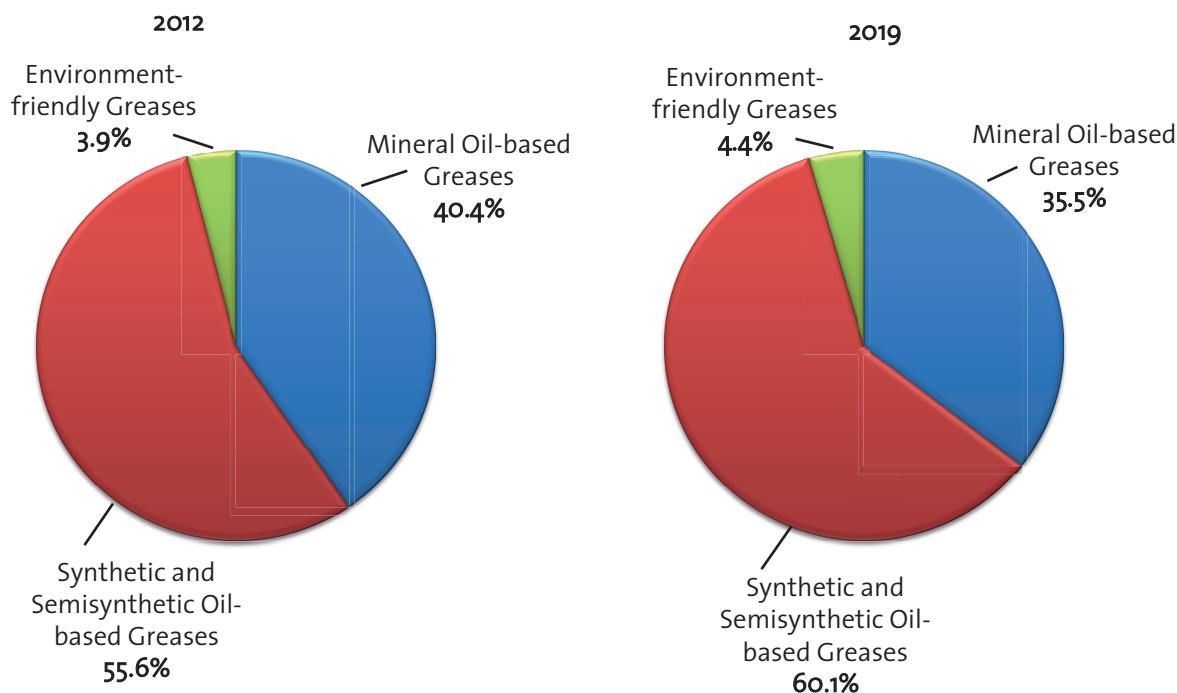
Modern technologies, advanced equipment, environmental legislations as well as the application of new materials and systems are continuously demanding improvements equally in mature and emerging regions. Apart from innovation and advancement, the grease market struggles for solutions that are professionally adjusted to applications and specific customer needs. Due to inadequate recommendations, many customers still use grease incorrectly, especially at the wrong place, and thus destroying the overall performance of the grease and the equipment.

Even if a grease supplier or distributor has a very wide range of greases, the selection is hardly ever a straight forward matter. The process of choosing the grease with the right physical and chemical properties for the application is quite complex.

The majority of industrial greases manufactured today predominantly uses mineral oil as fluid component. Mineral oil-based greases provide a satisfactory performance in many industrial applications and are less expensive in comparison to synthetic and semi-synthetic oil-based greases. Moreover, it is proven that in case of extreme temperatures, these greases provide better stability; however, they are less durable in comparison to other two types. While the mineral oil-based greases accounted for 40.4% of the global industrial grease market revenue (in 2012) and are still dominant with regard to the volume consumed, synthetic oil-based greases are preferably employed in more severe or even quite exotic applications. In 2012, revenues for semi-synthetic and synthetic oil-based greases amounted to 55.6% of the global industrial grease market mainly due to higher prices (Fig. 4).

The most popular thickeners are metallic, mixed and complex-metallic soaps, which yielded 92% of the revenues generated by the global industri-

Figure 4 Percent sales breakdown in global industrial greases market market in 2012 and 2019 (Source: Frost & Sullivan 2014).



al grease market in 2012. Metallic soap thickener may include lithium, aluminum, barium, clay, polyurea, sodium, and calcium soaps. At present, lithium soap greases are the most dominating products in a global market that generated 52% of the global market revenues in 2012. Apart from the metallic soap greases, the complex thickener-type greases are rapidly gaining market popularity. These complex products often combine the conventional metallic soap with a complexing agent. One of the main reasons why these products are more and more appreciated by end users is related to their high dropping point and excellent load-carrying abilities.

Regarding the overall grease production cost, a significant proportion consists of the amount of soap that is required to achieve a certain National Lubricating Grease Institute (NLGI) grade as its solvating power affects the amount of soap needed. Besides soap type greases, also non-soap thickeners such as bentonite and silica aerogel are systematically gaining attention from the key industry participants such as Klueber, Petrofer and Quaker. These products are typically required by end applications that use greases in equipment or machinery operating in an extremely high-temperature environment.

Additives decide about the product competitiveness in the market. Therefore, there is a large variety of highly innovative products that are added to industrial greases. At present, the most extensively used additives are oxidation and rust inhibitors, extreme pressure, anti-wear, and friction-reducing agents.

2.4 Market Growth Direction

In 2013, the total industrial grease market generated \$1,169.3 million and it is expected to grow at a compound annual growth rate (CAGR) of 6.6% between 2012 and 2019 (Frost & Sullivan 2014). This growth is relatively high despite of the increasing number of challenges, competition and legislative changes. The increasing need especially in emerging countries such as Brazil, Russia, India, China, and South Africa (BRICS) for improved performance and reliability as well as the sheer speed at which technology is moving drives the growth of this highly attractive market. Despite the fact that the industrial grease market is rapidly developing and changing, the dominant end user sector is not changing much. For many years, typically machinery and heavy industry as well as the infrastructure sector constitute the largest segment in terms of applications of mineral greases and less often application of synthetic industrial greases. Other equally important, however smaller end-user segments

include pulp and paper, aerospace, mining, food processing, and power generation. With regard to bio-based greases, they receive impressively increased attention for marine and food-grade applications.

Interestingly, there are a group of customers in the automotive, aviation and mining segments as well as machine designers or builders that require suitable lubricating greases regardless of whether such products are feasible, costly, and widely available or require special development and improved manufacture technology. These customers are strongly influencing the research and development and hence the innovativeness of industrial greases.

2.5 Stimulating Factors Affecting Industrial Grease Markets

Year-by-year the industry grease manufacturers are facing an increasing number of challenges, drivers and constraints. It is well-known that the industrial grease market is not a simple market. It is impacted by different factors that often vary depending on the situation and economy. The most influencing challenges are related to environmentally-oriented legislations, regulations and certificates. High environmental concerns drive the need for more advanced, effective, and safe industrial greases. Legislative requirements affect the grease composition as it is controlled how and where the greases are stored, especially the "used greases". In this case legislative pressure accelerates the market growth; however, often significant legislative changes are problematic to small and medium-sized companies that do not hold a strong share in the market and are not strong enough to compete with larger manufacturers. Any change in composition extorted by legislation requires additional finances and delay in commercialization in the case when the product is registered. This legislative pressure, especially constantly tightening rules, restrains the immediate use of certain, innovative greases by end users. Other forces that accelerate the market growth combine the extensive range of industrial applications supported by technological improvements that introduce more sophisticated and efficient greases as well as awareness campaigns supporting bio-based products. The purpose is to increase the end users' knowledge about the performance benefits of bio-greases. Most of them still consider environmentally friendly greases as detrimental in terms of performance.

There is one factor that in general accelerates the revenue market growth and at the same time restrains the volume consumed. This factor is the improved industrial grease quality. On the one side,

higher quality products are attractive and appreciated in the market especially due to the extended durability and shelf life. So it became an advantage for higher quality industrial greases to last longer and be more effective. Because of this, end users do not need to replace these greases as often as is in the case of more conventional products. This clearly reduces the need for frequent grease replacement and parallel saves time, money and reduces the amount of used greases. Regarding restraining factors, the most meaningful one is the unstable economic situation. It influences the financial fluency of each of the industry sectors that apply greases. This often leads to reduced interest in more innovative and advanced industrial greases as manufacturers are skeptical and not willing to financially support research and development (R&D), especially at the time when everybody is looking for savings. Another restraint as it was mentioned earlier is caused by the fact that grease markets depend on the industrial customers and their overall market situation. The economic situation impacts the demand for different types of industrial greases as well as the need for certain equipment and grease replacement. Also high switching costs caused by typically low industrial grease compatibility lead to minimal willingness to switch to new products as well as to products offered by other manufacturers. It is quite comfortable to use the grease originally applied. However, when the whole equipment (and associated process chains) is immobilized, it is highly recommended to choose another grease.

At the end of the restraining factors list, there is competition. Competition not only results from multinational companies but also from cheaper and often lower quality products typically from Asia. Although the competition provides high entry barriers for new market entrants, it can be possible for the manufacturers of lower quality greases or customized products with limited availability to challenge these barriers. In the global grease market, often price is still the first decisive factor during decision making. The second one considers technology performance and innovativeness.

To conclude, it is still highly reasonable to expect a continued systematic growth of the global industrial grease market in the near. The same estimate is realistic for bio-based materials used to manufacture industrial greases.

2.6 Industrial Greases Market Trends

At the moment the most significant market trend is related to the fact that industrial greases are under a very strong pressure as they need to be developed for modern and often extremely

demanding applications where high pressure, temperature and speed are the main requirements. Because of this, the manufacturers are continuously investing in new products and lubrication solutions by improving thickeners, additives and even based oils. This might be a potential opportunity for bio-based materials. Moreover, grease manufacturers are anticipating future demands and trends by following the direction of market development. High quality and innovative greases are significantly driving down maintenance costs and increasing the equipment as well as the whole production plant productivity. There is a general trend towards continuously improving the quality and performance of industrial greases as end users are more demanding. Simultaneously, advanced greases protect the equipment and machines better, enhance the reliability of working parts and improve the profitability. Therefore, major trends and developments are related to the fact that often the choice and adaptation of greases for the right application can be a huge challenge which needs to be addressed by manufacturers to meet the customers' needs.

At the same time it is critical to guarantee the consistent product performance with in-depth support knowledge. A long life under high-temperature conditions and considerable low-temperature fluidity is required for industrial greases used in bearings of engine electrical components. Normally, semi-fluid greases offer a prolonged protection. Another product trend is related to increasing the number of plastic elements. As an increasing amount of plastic material instead of metals is used, especially for the purpose of weight-saving, synthetic hydrocarbon greases are used to avoid any adverse effects on plastics.

Further trends are caused by other new, often niche applications that require special greases fulfilling specific requirements, such as conductivity and vacuum conditions. The trend typical in most industries is to maintain their machines for longer periods without re-greasing, and thus, especially synthetic greases are considered to be the best solution. One can also find some grease that addresses multiple applications. Multi-purpose industrial greases are highly popular between manufacturers as these products cover a wide range of applications, simplifying maintenance and reducing customers' stock levels. The high-temperature greases for the most severe conditions exhibit an increased popularity especially when we consider the well-established European and North American market.

2.7 Market Opportunities for Bio-based Materials

It can be monitored that there is a market opportunity for bio-based materials in the global market of grease production, especially for greases applicable in the marine sector and other environmentally sensitive areas. An increased availability and number of greases that are based on vegetable oils such as rapeseed and soybean oil can be observed. In 2012, oils based on rapeseed oil accounted for 26.5% and those based on soybean oil for 32% of the bio-based greases market. However, from the other side it seems that end users are not yet ready for such a drastic change, especially as the performance and durability require some additional developing effort. In addition, bio-based greases require the usage of comparably expensive raw materials which increases the overall price. As industrial grease end users quite price sensitive, they are not willing to pay for premium bio-based solution. To help to increase bio-based materials' popularity in industrial grease markets, governmental and legislative rules are required. Additionally, reduced prices and improved performance will also support the market opportunities for bio-materials in greases. It is also critical to provide industrial greases that do not contain lead or heavy metals which are considered to be harmful to human health and the environment. Additionally, it almost became a rule to offer products that are biodegradable, non-toxic and hence not harmful to the environment. Non-biodegradable greases of any kind should always be handled with great care, particularly by avoiding any contact with the skin.

3 Conclusions

There is a constant drive in the industry to create machines that are smaller, more sophisticated, and compact. At the same time, the machinery industry are building parts to serve multiple purposes. Hence, when working parts and moving components are brought closer to one another, the heat released will be higher than it would be under normal circumstances. Therefore, more customized, innovative, and advanced industrial greases are expected to drive the market economy whereby high quality, environmentally suitable, and more durable, multi-functional and efficient industrial greases are the most important end user needs at the moment. Biodegradability is also an important characteristic but to be made of bio-based material is not so critical for greases at present. Some bio-greases are present in key industry participants' product portfolios but they are often established for marketing purposes to demonstrate the manufacturer's willingness to be flexible and sustain-

able. Realistically saying, the industry seems to have no room for less effective products; therefore, industrial customers have to wait a few years before bio-based greases can offer equally attractive properties to those that currently dominate the global market. However, new regulations and requirements, environmentally suitable or acceptable standards, engine hardware changes, and the extension of oil drain intervals will put additional pressure on industrial grease manufacturers to increase the performance, durability, and robustness of greases as mechanical equipment operating conditions are becoming harsher as well.

There is an overall large potential for bio-greases; however, improving their performance will largely depend on manufacturers' promotions backed up by the necessary government policies that can enforce the usage of bio-lubricants in key areas such as hydropower plants.

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