

Research Paper

Exploring market knowledge in product development of chemical firms

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Firms can enhance product innovation performance by continuously staying in touch with customers and the market in general. While studies on market oriented product development have identified several general dimensions of market knowledge used in product innovation, the nature of market knowledge that is specifically important in the chemical industry remains unclear. Because firm relevant knowledge resources are increasingly seen as being industry specific, filling this gap becomes more relevant. This study uses a multiple case study of six product innovation projects in six different companies to identify important market knowledge dimensions in the product development of chemical firms. Aggregated results from the six cases point to segment knowledge, application knowledge, product usage knowledge, and customer knowledge as being important market knowledge dimensions. Implications for theory and practice as well as avenues for further research are included.

This paper reports on research that aimed to identify the nature of market knowledge that is of importance for market oriented product innovation in the chemical industry.

As in many manufacturing industries, product innovation is important for chemical firms to keep their competitive advantage (Heinzelbecker, 2005). Consequently, it is no surprise that well respected firms in the industry have articulated product innovation strategies. The Dutch life science and material science company DSM, for instance, has appointed a Chief Innovation Officer and has set long term product innovation targets. Another example is Solvay. This Belgian chemical company has announced that 30% of the firm's income should come from new products or technologies developed within the past five years.

Product innovation can be described as initiating a new product idea and bringing it to the market. It consists of a collection of tasks that have to be performed by employees from multiple departments such as research, mar-

keting and manufacturing (Sheremata, 2000). Within product innovation, processing market information is important. Already in the 1970s, Cooper (1979) concluded that including market information in new product decision-making was one of the controllable factors that contributed to new product success. Today it is widely accepted that companies have to stay in touch with their customers and the market in general as a precondition for successful product innovation (see e.g. Cooper, 2001; Kirca et al., 2005; Montoya-Weiss and Calantone, 1994). As Leonard (1995: 177) indicates, it seems that no information is more important to a firm "than information flowing in from the market, as this information shapes science into commercial product or service."

1 Views on market knowledge

Two streams of research that can be used as background for researching market

knowledge in product innovation are research on market oriented product innovation and studies on the Knowledge Based View of the firm.

1.1 Market oriented product innovation

In marketing science a firm's market focus and market information processing is captured by the concept of market orientation (Hunt and Lambe, 2000). Initially, two perspectives on market orientation emerged which, to some extent, can be considered as opposite viewpoints (Day, 1994; Homburg and Pflesser, 2000; Lafferty and Hult, 2001). The first perspective was developed by Kohli and Jaworski (1990) and is centred around behaviour while the second perspective, developed by Narver and Slater (1990), has a cultural viewpoint. Both the behavioural and cultural view of market orientation have weaknesses with respect to conceptualization and measurement (Oczkowski and Farrell, 1998), and there is debate on the value of each perspective (Jaworski and Kohli, 1996; Lafferty and Hult, 2001). Still, both perspectives are able to show that information on customer needs and wants is central to market orientation. Additionally, both balance an internal and external organizational view, both argue that the firm as a whole should respond to identified customer needs, and both maintain that the scope of market orientation goes beyond customers and incorporates competitors and the forces that shape customer needs such as governmental regulations.

How can a firm's market orientation enhance product innovation performance? The marketing literature answers this question by linking market information processing to strategy making and execution, particularly innovation. With few exceptions, it argues that a market oriented culture and the associated information processing behaviour reduces risk associated with developing new products and, therefore, enhances their success. Especially from the mid-90s onwards, many studies link market orientation to product innovation performance (Atuahene-Gima, 1995; Gatignon and Xuereb, 1997; Li and Calantone, 1998; Veldhuizen et al., 2006). Additionally, the mediating role of product innovation in the market orientation – performance relationship has been analyzed (Han et al., 1998; Langerak et al., 2004). A meta-analysis by Montoya-Weiss and Calantone (1994) found that the proficiency of

employees to perform marketing activities during the product development process has a strong positive effect on new product advantage. In a similar vein, the literature review of Brown and Eisenhardt (1995) indicated that a significant number of studies highlight the importance of customer involvement for the effectiveness of product concepts and better product designs. Also, a meta-analysis by Kirca and colleagues (2005), which included 114 studies, confirmed that a market orientation has a positive effect on organizational performance via product innovation. Besides product development effectiveness a market orientation may also improve product development efficiency. For example, based on an analysis of data from 103 product development projects from the chemical industry, Cooper and Kleinschmidt (1994) found that including a customer viewpoint into the new product development process reduced product development cycle time significantly. Additionally, it has been shown that market orientation not only enhances incremental product innovation performance but also has a positive effect on radical innovation (Atuahene-Gima, 2005; Baker and Sinkula, 2007; Kyriakopoulos and Moorman, 2004).

1.2 Knowledge Based View of the firm

Knowledge can be defined as 'information in context' (Nonaka et al., 2000). Within the framework of the Knowledge Based View of the firm, knowledge is regarded as important resource in organizations. It is argued that, in contrast to physical resources, organizational knowledge and its generation, transfer, integration, and application are idiosyncratic to the firm and are therefore an important source of competitive advantage (Grant, 1996; Kogut and Zander, 1992). Also, knowledge may extend its value more broadly than physical resources because it can be simultaneously used for multiple ends (Itami, 1987). Conner and Prahalad (1996) even go so far as to state that knowledge resources are the most important resources of the firm. Sometimes a distinction is made between information and knowledge (e.g. Ackoff, 1999). While information is seen as descriptive in nature, related only to past and present events and situations, knowledge is specifically predictive in that it allows future insights to be gained from past and current circumstances (Kock et al., 1997). However, in practice a distinction between knowled-

ge and information is hard to make and therefore we will use the term 'knowledge' to point to both information and knowledge.

From a marketing perspective two knowledge flows are particularly important for product development: the generation of market knowledge from the market environment outside the firm and its integration with technological knowledge to develop product designs (Allen, 1971; Ancona and Caldwell, 1992; Atuahene-Gima and Murray, 2007; Grant, 1996; Li and Calantone, 1998). To put these knowledge flows in practice requires management to improve knowledge storage and access, and facilitate an environment conducive to knowledge use. In addition, it requires organizational members active in day-to-day product development activities to acknowledge their existence and usefulness.

2 Market knowledge and product innovation

Insights from studies on market oriented product innovation and the Knowledge Based View of the firm may be combined in order to arrive at an inventory of general market knowledge dimensions in product innovation. Adams and colleagues (1998: 409), for instance, identified two dimensions of market knowledge: 'product concept development information' and 'business data'. Product concept development information "included all mentions of customer needs, what the customers were like, and designing the product...to achieve the concept." The second dimension, business data, included "all mentions of emerging trends in the market place, of competitors, of estimates of market size, segments and feasibility, and of whether or not this was a good business for the organization." Veldhuizen et al (2006: 361) make a similar distinction between customer information, concerning the understanding of customer problems, and environmental information, concerning competitor and general industry information.

While these general categorizations are of great value for theory and practice, it appears that knowledge which is created and transferred within an organization is inextricably tied to its specific context (Foss, 1996). One of the most important backgrounds in which organizational knowledge is situated is its industry environment (von Krogh et al., 1994). An industry environment shapes managers' perceptions because it provides an analytical context

by which managers cope with uncertainties. Industries imbue organizational knowledge with meaning (Kogut and Zander, 1996). 'Industry recipes' frame managers' choices as they make decisions under ambiguous and uncertain circumstances. Thus, knowledge resources seem highly industry specific. As Winter (1987: 175) claims: "lessons derived from experience in one industry may be very misleading guides to knowledge related strategic resources in another." King and Zeithaml (2003), for instance, identified dozens of knowledge dimensions in hospitals and textile firms and concluded that only *one* comparable knowledge dimension between the two contexts could be identified. Thus, while general dimensions of market knowledge in product innovation have been developed, we expect that relevant dimensions may differ across industries. This paper deals with market knowledge in product innovation in the specific case of the chemical industry, asking "*what market knowledge is used in the product development of firms in the chemical industry?*" We aim to present a comprehensive and empirically derived framework of market knowledge dimensions that is relevant for both researchers and practitioners.

3 Research setting and methodology

A multiple case study strategy was used to investigate market knowledge as used in product development of firms in the chemical industry. This strategy is appropriate for two reasons. First, this study concerns a complex phenomenon (market knowledge) in the dynamic setting of product innovation in established firms. Looking into such a topic benefits from the extensive interaction with research subjects that case studies allow for (Yin, 1994). By using this strategy overlapping constructs can be disentangled and contexts can be taken into account (Lee, 1999). Hence, case studies allow for exploring the detailed nature of knowledge dynamics in product innovation. Second, our understanding of market knowledge in product innovation is incomplete and a case study strategy can be used to extend existing theory to new domains (Eisenhardt and Graebner, 2007; Yin, 1994). While single cases can richly describe the existence of a phenomenon, multiple case studies typically provide a stronger base for theory building and extension (Glaser and Strauss, 1967).

The chemical industry is a capital inten-

sive process industry which creates and transforms chemical substances to provide the market with functionally advantageous non-assembled products. It is dominated by large multinationals, has its roots in Europe, and is over a hundred years old (Cesaroni et al., 2004; Mahdi et al., 2002; Van Gils, 2010). We restricted the chemical industry to the C20 NACE code.

Our unit of analysis was the product innovation project in a chemical firm. This small unit of analysis helped to focus data collection because it allows for studying well-defined organizational events (Yin, 1994). Case selection started by contacting chemical firms that were members of trade organizations and research consortiums in the Netherlands, and/or the European Industrial Research Management Association. An additional selection criterion was that companies had a significant presence in the Netherlands, Belgium, or Germany for reasons of accessibility. After negotiating access we were able to work with six chemical companies. Because prior research has shown that most marketing and product innovation activities take place at the level of the business unit (Adler et al., 1999; Piercy,

1985; Workman et al., 1998), the business unit instead of the corporate level was selected as organizational context. Our first firm contacts referred us to persons working in the business units. The sizes of these business units ranged from €270 to €4,400 million in annual sales revenue, with an average size of €1,100 million. As a second step in case selection we selected one product innovation project per business unit as main case (Table 1). The products that were the results of these projects had to be just before market introduction or had been introduced into the market less than two years ago. The rationale for this requirement was that long finished projects would reduce the changes of contacting suitable respondents and the ones that could be contacted might have problems remembering the details of the projects. Also, market introduction can be considered as an intermediate measure of project success (Seidel, 2007). Because prior literature suggests that market knowledge is essential for project success, studying successful projects increased the changes that extensive market knowledge could be identified.

Data were collected by interviewing actors

Table 1 Overview of cases

Project	Cycle time	Business unit turnover Business unit focus	Interviews
Heat "New grade of plastic in existing application." ¹	S ² : 2003 I ³ : 2008	~ €700 million Materials	12
Green "New chemical ingredient in existing application."	S: 2003 I: 2007	~ €800 million Specialty chemicals	4
Diffuse "Existing grade of plastic in a new application."	S: 2003 I: 2006	~ €300 million Materials	4
Anti-resist "New grade of fibre in new application."	S: 2004 I: 2007	~ €400 million Materials	11
Foam "New type of foam in new application."	S: 2005 I: 2008	~ €4,400 million Materials	9
Additive "Existing polymer in new application."	S: 1999 I: 2004	~ €250 million Specialty chemicals	4

¹ Description based on the perspective of the business unit

² S = Project start

³ I = Market introduction

involved in the product innovation project, and organizational members who were related to this group such as senior managers. The use of multiple respondents allows information to be checked, thus providing the opportunity to control for potential biases of individual respondents (Dougherty, 1990; Goldon, 1992; Huber and Power, 1985). The interviews contained both general and more specific questions. In most cases, a single question ("Could you please describe how the project developed over time?") was enough to trigger the main process story. After the initial story, we followed up with in-depth questions, focusing on specific dates, working practices, milestones, events, and outcomes. Since there was no list of people that had been or were involved in the projects under study, the selection of respondents was based on information provided by other respondents. We finished data collection when additional data resulted in limited additional understanding (Glaser and Strauss, 1967; Lee, 1999). Respondents ranged from senior managers to operational staff and the interviews lasted between 50 minutes and 2.5 hours. Notes were taken and all interviews were taped and transcribed verbatim. Most interviews were carried out on-site, but three interviews were by telephone because respondents were located more than 500 kilometres away. Data collection started in 2006. Interview data were supplemented with archival data such as new product proposals, product announcements, product catalogues, presentations, and business press articles to cross-check initial findings. Overall the combination of interviews and archival data collection enabled a rich understanding of market knowledge resources used in product innovation in the context of the chemical industry.

Data analyses started with examining data from single cases. The aim was to get familiar with each case as a stand alone entity. We divided information in meaningful fragments (Miles and Huberman, 1994). These fragments were labelled with a few words to indicate the meaning of the fragment. For coding and data handling we used the qualitative data analysis package NVivo. During coding we generated preliminary notes of insights that emerged per case. This description was fed back for review by several respondents. We focused on similarities and differences between cases. Significant discrepancies and agreements were noted and further investi-

gated. To further sharpen our findings and test their validity the cases were also systematically compared with existing literature (Eisenhardt, 1989). Iterating back and forth between data and theory resulted in the identification of a robust set of market knowledge aspects, such as, for instance market segment size, growth rate, and stakeholder behaviour. We then aggregated these aspects into four market knowledge dimensions as used in product innovation processes in chemical firms.

4 Market knowledge dimensions in product innovation

Our findings suggest that new product teams in the chemical industry use significant amounts of market knowledge in successful product innovation. This market knowledge is multidimensional and consists of *segment knowledge*, *application knowledge*, *product usage knowledge* and *customer knowledge*¹. To successfully initiate a new product idea, develop it into a physical product, and introduce it into the market, project members had to take all of these dimensions into account. All four dimensions were found in projects in the area of specialty chemicals, as well as in projects in the area of materials. We will now discuss each of these market knowledge dimensions in some detail.

4.1 Segment knowledge

In line with other scholars (Daft and Weick, 1984; Day and Nedungadi, 1994) we do not assume that market environments are unambiguous realities. Project members and higher level managers make sense of their surroundings by defining market segments. These segments are given meaning through selective search, perception and simplification. They were based on experience and data already available, interactions with other organizations, and influenced by functional and personal backgrounds.

During product innovation market *segment knowledge* was searched for. Search was specifically aimed at quantifying *segment size*, in terms of volume or value, and *segment growth rate*, and at *stakeholder behaviour* (other than customer behaviour) that may influence customer preferences such as competitor moves and activities of distributors and governments (Table 2). Quantifying market size was main-

¹ In this research, the term 'customer' relates to business-to-business customers of chemical firms such as downstream manufacturers.

Table 2 Segment knowledge

Project	Segment	Focus area(s) / Examples		
		Size	Growth rate	Stakeholders (others than customers)
Heat	Automotive 'under the bonnet' applications			"[For project Heat] we learned that temperature requirements of 'under the bonnet' applications were going up due to governmental regulations." <i>Product manager</i>
Green	Application area for chemical ingredient		"For this project, we used estimates on developments in market volumes of the chemical ingredient." <i>Business manager</i>	"...our business plan for [project Green] included a competitor analysis based on patent data." <i>Business development manager</i>
Diffuse	Edge-lit signage	"I tried to look at the [market] volume of edge-lit material for signage which was significant." <i>Business developer</i>	"...this information pointed to ultra slim edge-lit displays being a trend." <i>Product manager</i>	
Anti-resist	Tires			"We learned that reducing rolling resistance due to mandatory standards by the EU was a main priority of a large group of tires manufacturers." <i>Business manager</i>
Foam	High performance foams	"At the start of the project we quantified the market and identified certain applications for this [foam] material." <i>Marketing manager</i>	"[Global marketing] looked at volumes and future market expectations of high performance foams." <i>Sales manager</i>	
Additive	Plastics	"Our team managed to get knowledgeable about the sales volumes of several plastics." <i>Senior research associate</i>		

ly done by desk research while segment growth rate and stakeholder behaviour was identified by using desk research, customer contacts, and visiting conferences.

The market segment knowledge dimension has some parallel in the marketing and product development literature. It reflects what Jaworski and Kohli (1996: 126) have called "a sensitivity to the underlying forces that shape a market or an industry." Also Veldhuizen et al. (2006) identify competitor and industry information as important aspects of environ-

mental information that is used in product innovation. A similar type of market knowledge in innovation is called 'business data' by Adams and colleagues (1998).

Good examples of efforts to quantify segment size could be found in projects *Diffuse*, *Foam*, and *Additive*. In the mid-90s the business unit in which project *Diffuse* took place, developed and introduced a specific transparent plastic sheet. This sheet had colourless light diffusing particles that cause light to diffuse forward. It was specifically engineered

for edge-lit signage applications, such as panels for airports, shopping malls, restaurants, and bus stops. It accepts light through its edges and redirects it to the surface for bright uniform illumination. This product was specifically targeted toward the edge-lit signage segment. As the head of innovation noted: *"Lighting has always been a defined 'meta-segment' where we sell our products and we always have worked on lighting applications in the past. Edge-lit signage is the specific market segment that is of interest when talking about this product."* In 2002, in response to customer feedback, a business developer made some incremental adaptations to the product which caused renewed internal and external attention for the sheet. Internally business developers mainly tried to quantify the market for edge lit signage by doing desk research. As the business developer put it: *"This renewed attention made us study market reports...I tried to look at the [market] volume of edge-lit material for signage, which was significant."* Desk research as market knowledge generation practice to quantify market segments was also used in projects *Foam* and *Additive*. The marketing manager of *Foam* indicated: *"At the start of the project we quantified the market and identified certain applications for this material....we studied market reports to get familiar with the market space and with applications. You can buy market reports on high performance foam and where that goes into. After that we had some idea of what the market really was."* In project *Diffuse* project members acted within a market segment that was already familiar to the organization. The market segment for edge-lit applications was developed and used in, for instance, strategy discussions before the start of the project *Diffuse*. In contrast to project *Diffuse*, the market segments in projects *Foam* and *Additive* were developed during the initiation of the projects. Project members in these latter projects experienced the limits of their market segment frame of reference which forced them to rethink their routines. They had to label a newly identified market segment and communicate it to the rest of the organization, and they had to get familiar with this new segment before investment decisions could be made. A large part of these projects consisted of just getting familiar with market segments that were totally new to the organization. As a sales manager involved in project *Foam* put it: *"At the start of the project the organization had never sold high performance foam before,*

so the market research on this market segment is new to the organization."

Projects were partly chosen on the basis of expectations concerning market segment growth. As a result, next to estimates on market segment size, also market growth rates were studied. Good examples of mapping growth rates are *Green*, *Diffuse*, and *Foam*. Project *Green* was focused on changing the feedstock and process technology of a chemical ingredient which could potentially influence the properties of the epoxy resin for which it was used. As the business development manager of *Green* explained, next to estimates of the market size for the chemical ingredient, the business plan for *Green* also *"had estimations on developments in market volumes and prices for our product."* While project members generally tried to quantify market segment size, for identifying growth rates qualitative information was added. In project *Diffuse*, for instance, additional qualitative data were gathered which reinforced the development team's conviction that edge-lit signage was a growing segment. To map dynamics in market segment size, next to desk research, additional market knowledge generation practices were applied. Product development teams complemented desk research by using (potential) customer contacts, and conferences and trade fairs to interact with the market. An example of using customer contacts to estimate growth rate is project *Foam*. In this project, a new product was developed in order to fill a gap that resulted from an incumbent foam producer phasing out a specific foam material. To estimate dynamics in the high performance foam market segment, marketing managers involved in *Foam's* development team were in direct contact with potential customers. As a marketing manager indicated: *"From a commercial point of view, first question was analyzing the reactions of customers of the incumbent material to the situation. Were we chasing a market space that was getting smaller because customers were also phasing out this material, or was it that they lost business because they couldn't continue what they were doing?"* Market knowledge generation practices in project *Diffuse* illustrate the use of conferences and trade fairs to estimate growth rate. As was pointed out by a product manager involved in project *Diffuse*: *"From attending trade fairs we learned about developments in the market. This information pointed to ultra-slim edge lit displays being a trend."*

A final area where market segment knowl-

edge was generated was the market segment stakeholders area. Mapping the behaviour of agents such as competitors and regulators in relationship with a market segment often provided the impetus to initiate a product development project or an early indication of the feasibility of a project. Examples of mapping the behaviour of market segment stakeholders are *Heat*, *Green*, and *Anti-Resist*. Project *Heat* clearly originated from studying developments in governmental regulations. By becoming aware of emission standards set by European Union and analyzing their impact on automotive 'under the bonnet' applications, *Heat's* home organization realized that their existing grade of plastic would not meet future heat resistance requirements of these applications. The need for efficient combustion engines, driven by Euro 5 and Euro 6 emission standards regulations, would result in engine designs with higher operating temperatures. At these temperatures the existing grade of plastic would melt and therefore existing customers were in need of a new type of plastic. As the product manager involved in *Heat* explained: *customers were in need of a new type of plastic. As the product manager involved in Heat explained: "Heat was born from market studies. We learned that temperature requirements of 'under the bonnet' applications were going up due to governmental regulations and we tried to anticipate by developing a new product."* For studying the behaviour of stakeholders, project members used the same practices as were used for mapping segment growth rates: desk research, customer contacts and visiting trade fairs and conferences. In project *Green*, for instance, the innovators mapped competitor behaviour by studying their patent activities from public sources. As the business development manager involved in *Green* put it: *"Next to estimates on developments in market volumes for our product market, our business plan included a competitor analysis based on patent data from patent databases."* While the employees involved in *Green* solely relied on desk research to map stakeholder behaviour, the product developers involved in *Heat* complemented desk research with conferences and industry meetings: *"I visited conferences and industry meetings where the automotive world presents future ideas and legislation influences on an ongoing basis....these visits, combined with studying trend reports were important sources of information [for project Heat]."* Product manager *Heat*. Finally, in project *Anti-*

resist, stakeholder behaviour was collected by using customer contacts and having conversations with them. As the business manager involved in *Anti-resist* indicated: *"We interviewed three of our customers back in 2004, which are the biggest three in this market and cover about 65%, and asked them what their future needs were and how these needs came to light. I can show you the data that reducing rolling resistance due to stricter mandatory standards defined by the European Union is an important customer concern. You can see that it is going on until 2012. We complemented the interview information with doing desk research."*

4.2 Application knowledge

A second market knowledge dimension that was identified is *application knowledge* (Table 3). Application knowledge is knowledge on customer applications requirements in which a new product (potentially) can be used. It can be seen as knowledge focused on the nature of the customer application for the newly developed product. At times application knowledge can be rather technical. Still this should be seen as market knowledge because it is about technical aspects dealt with by customers. While in some projects only one application was analyzed, in other projects employees focused on multiple applications. As a separate knowledge dimension, application knowledge has few precursors in the marketing and product development literatures. The following examples further explicate the concept of application knowledge.

After the market segment trend of increasing engine temperatures was identified in project *Heat*, application developers involved in the project were sent to customers to collect future heat requirements of turbo chargers and air-ducts applications which are part of vehicle engines. These future heat requirements were fed back to the research department of *Heat's* home organization and used as a research target for developing prototypes of the new polymer grade. As the product manager involved in project *Heat* explained: *"We already had running business in these applications [turbo chargers and air ducts]...we identified a market trend and asked our application developers to visit OEMs to identify future application requirements....Further in the project the OEMs also did application tests. Results from these tests were shared with us."* In project *Green* a main application for the chemical

Table 3 Application knowledge

Project	Application	Examples
Heat	1. Turbo-chargers 2. Air-ducts	"We already had running business in these applications [turbo chargers and air-ducts]...we identified a market trend and asked our application developers to visit OEMs to identify future application requirements." <i>Product manager</i>
Green	Epoxy resin	"For the business plan, we also gathered information on developments in the epoxy resin application." <i>Business development manager</i>
Diffuse	License plate system	"During the development phase of the project we had learned that our customer had more difficulties with creating the transparent license plate than with creating the lighting unit." <i>Product manager</i>
Anti-resist	Rolling resistance in tires	"In the development phase when we worked together with customers, it occurred to us that rubber tires are complex compounds with several ingredients. It is not one product that is mixed with our product, and then there is also the way of mixing that can cause differences in rolling resistance test results." <i>Project manager</i>
Foam	1. Aircraft luggage bins 2. Aircraft galleys 3. Aircraft lower wall panels	"With individual validation partners I moved from a market segment level to an application level...I gathered the customer requirements on aircraft interior components in which foam core material was used, such as luggage bins and galleys, and continuously kept customers informed and involved throughout the program." <i>Marketing manager</i>
Additive	1. Polymer chain extension in plastics 2. Flow modifying in plastics 3. Dispersing in plastics	"After feedback from a potential development partner, our team converged to the polymer chain extension application having tremendous value for customers." <i>Senior research associate</i>

ingredient was epoxy resin. Project members in this project gathered information on developments in this specific application which were used in product development decisions. In *Diffuse*, project members collected information on the specifics of a newly developed license plate system developed by the potential customer. In project *Anti-resist* project members learned about 'rolling resistance in tires'. As the project leader indicated: "We already sold products that are used in tire reinforcement, but this application was new to us. This is quite exciting because we do not disturb our current tire application. Market segment is still tires, but it is a new application in the tire market. Application requirements for rolling resistance were hard to pin down, but in interaction with us customers shared certain expectations, which, eventually, we could meet with our new product." In *Foam*, project members gathered application

requirements on several aircraft interior components such as luggage bins, aircraft galleys, and aircraft lower wall panels. During the project there was constant interaction on the specifications of these applications between *Foam* project members and potential customers. Also in project *Additive* application knowledge was gathered. Project members discovered new applications while collaborating with potential buyers. Initially, they had thought of *Additive* as a product to improve the flow of plastics, but testing in the market revealed that other applications were far more interesting. As the business manager explained: "We received market feedback with unexpected results: this is not a plasticizer, this is a dispersant. Our people did not know what a dispersant was or what you disperse, it was a little bit shooting in the dark." After this discovery the *Additive* team focused on the newly discovered application and gathered more

information on 'dispersing in plastics'. Additionally, the team discovered other applications which resulted in new information inquiries such as 'polymer chain extension in plastics'.

Generating application knowledge often comes down to interactions with customers or potential customers, mainly in the development phase of the product innovation project. As the head of new business development involved in *Diffuse* explained: "My colleague had a very close relationship with [customer] to develop this license plate system. In this relationship, knowledge on the application was created." The same practice was observed in project *Foam*. A quote from the project manager of this project illustrates how important it was to discuss application knowledge with partners that may be future customers: "I would say that commercially we did a good job. We selected six validation customers

which was enough to discover most of the requirements of the [aircraft interior components] applications...we dealt with them with a fair amount of personal contact." In project *Additive* customer interaction on application knowledge even resulted in a joint patent: "Our [Additive] team managed to get very close with potential customers. We had either partnerships, joint developments, or close relationships. On the polymer chain extension application this even resulted in a joint patent between our company and the potential customer." - Senior research associate *Additive*.

4.3 Product usage knowledge

The third market knowledge dimension we identified is *product usage knowledge* (table 4). Product usage knowledge refers to knowledge on how a product is used by customers and how a product behaves in downstream

Table 4 Product Usage Knowledge

Project	Product usage	Examples
Heat	New grade of engineering plastic	"Because we only did internal testing with the new grade [of engineering plastic] we were in need of real life tests with customers. Feedback of these tests was used to adapt prototypes." <i>Product manager</i>
Green	New chemical ingredient	"We started sending some samples in advance from the pilot plant in 2006 to check if we were not making mistakes." <i>Business manager</i>
Diffuse	Existing grade of engineering plastic	"They [the customer] needed our product in a specific shape, so we produced sheets and laser-cut them in specific shapes...There were several interactions between us and the customer to come up with the right product." <i>Business developer</i>
Anti-resist	New grade of fibre	"We tested our prototype products with customers and they thought it was very attractive. However they also discovered some limitations. Based on that feedback we adapted the product and generated a second product and it is expected that this is going to be the main version of the product." <i>Project manager</i>
Foam	New type of high performance foam	"Working with several validation partners was quite important. They tested initial prototypes of the material to see if it would meet their set of requirements and fed their experiences back to us...We were open to them, showing them how we developed it and the different test methods that we used." <i>Marketing manager</i>
Additive	Existing polymer	"In the beginning we had low molecular weight additives, which are typically used as solvents, dispersants, or flow modifiers. A little bit different but the idea is the same: getting lower polymer weight, lower viscosity, and better flow..then the team made a sample that increased viscosity, so the opposite approach. That was what customers really loved, they really could use that." <i>Business manager</i>

manufacturing processes. For instance, if an organization has a long history of selling a specific engineering plastic it probably has developed deep knowledge on how this product behaves in downstream manufacturing processes. In contrast, if a product is under development there is a limited product history and the organization has limited product usage knowledge. It has to develop this knowledge by engaging in customer tests in the course of the product development trajectory. Product usage knowledge is distinct from application knowledge. In one product development project an organization may target applications that are familiar to the firm with a new product or technology. In this case the organization already has significant application knowledge and limited product usage knowledge at the start of the project. In another project, in contrast, the organization may use an existing product or technology to target unfamiliar applications. Product usage knowledge too has few precursors in the marketing and product development literatures. The following examples further illustrate the concept of product usage knowledge.

The grade development trajectory of project *Heat* consisted of several rounds of technical testing and dealing with issues of manufacturability. This trajectory brought the number of polymer recipes down from about 25 to two. However, the new grade was then still not tested with customers. Although the research group wanted to do more internal tests, the product manager insisted on testing the remaining recipes with customers. *Heat's* project team managed to develop collaborations with several engine part producers and two European automotive OEMs². These downstream partners tested the remaining recipes by using small amounts of the new product in their manufacturing processes. Test results were shared with *Heat's* project members and this product usage knowledge was used to refine product prototypes. In project *Green* the organization had to build a new plant for manufacturing the new product. From the moment the pilot plant was capable of producing a product that came close to the desired end product, project members started sending samples to customers for testing purposes. The feedback on these tests allowed project members to refine the initial product until it was ready for market introduction. As was indicated by the business manager involved in proj-

ect *Green*: "We started sending some samples in advance from the pilot plant in 2006 to check if we were not making mistakes." Also in project *Diffuse* there were several interactions between project members and the customers to generate product usage knowledge which could be used to come up with the right product for the application. In project *Anti-resist* generating product usage knowledge even led to the development of a second product which was being deployed next to the original product and is expected to become the main version of the new material. *Foam* project members had discussions with a restricted set of six launching customers that all tested different grades of the new foam material during the development phase of the product development trajectory. Discussions with these partners were quite open and after generating product usage knowledge, this knowledge was used to refine initial prototypes. As the marketing manager involved in project *Foam* explained:

"Working with several validation partners was quite important. They tested initial prototypes of the material to see if it would meet their set of requirements and fed their experiences back to us... We were open to them, showing them how we developed it and the different test methods that we used." This product usage knowledge was totally new to *Foam* project members. Normally they talked about plastic materials with validation partners and now they were discussing a foam product. Again the marketing manager explains: "The type of discussions we had with customers was completely different from what we normally have. It is not an injection moulding material. We did not talk about mould temperature, conditions of raw materials or flow lines." In project *Additive* different product samples were tested and based on the product usage knowledge that was generated, project members discovered additional product properties that gained a lot of customer interest: "In the beginning we had low molecular weight additives, which are typically used as solvents, dispersants, or flow modifiers. A little bit different but the idea is the same: getting lower polymer weight, lower viscosity, and better flow.... then the team made a sample that increased viscosity, so the opposite approach. That was what customers really loved, they really could use that." - Business manager *Additive*.

Practices to generate product usage knowl-

2) OEM = Original Equipment Manufacturer. In the context of the automotive industry OEMs are, for instance, Volkswagen and Renault.

edge were comparable with the practices identified to gather application knowledge: interactions with customers or potential customers, mainly in the development phase of the product development projects. In project *Heat*, for instance, project members had interacted with customers for testing prototypes: “We were able to use our product development partners to get market feedback during development. We had a really good collaboration with them when we were testing prototypes. We had contact with them every 1.5 months.” Another example comes from project *Anti-resist* where the business manager involved in the project told about interactions with customers to gen-

erate product usage knowledge: “We collaborated with a number of customers, using a secrecy agreement. We had our prototypes and asked them to have a look at them....we already tested the product on lab-scale but then we could say we were testing the product in real tires.”

4.4 Customer knowledge

We call the last market knowledge dimension *customer knowledge*. This knowledge dimension does not refer to customer needs and wants, which is predominately captured by application and product usage knowledge, but to additional useful information about

Table 5 Customer knowledge

Projekt	Customer	Focus area(s) / Examples	
		Contact information	Decision making unit
Heat	1. Tier 1 engine part manufacturers 2. Automotive OEMs		“We know who is most important in this market segment, so internally we selected a set of potential partners. Then we convinced the decision makers to work with us on the project.” <i>App. development manager</i>
Green	Epoxy resin producers		“We learned that some of our customers, for example in the aeronautics value chain, have longer qualification and decision processes than others.” <i>R&D manager</i>
Diffuse	Traffic safety solutions OEM		“At the start [of the project] I visited this guy [at the customer]. His project was not really serious. He had a small laboratory and was working with students. However at a certain point in time I learned that this organization really wanted to commercialize the license plate system.” <i>Business developer</i>
Anti-resist	Tire manufacturers	“....we found out that the fibre people at our customer did not really understand our new product. These fibre people put us in contact with the materials group of their company that could better understand our new product.” <i>Business manager</i>	
Foam	1. Foam cutter 2. Aircraft interior component OEMs	“The reality is that customers who use our thermoplastics for injection moulding are also potential customers for the foam form as well. So we know all about them and the contacts were already there.” <i>Marketing manager</i>	
Additive	1. Plastic producers 2. Plastic recyclers	“In the following months we tried to generate contact information on all major plastics companies in North America, Europe and Korea.” <i>Senior research associate</i>	

customers. Customer knowledge too has few precursors in the marketing and product development literatures. With respect to customer knowledge, project member search was mainly focused on *contact information* of existing and potential customers, and the customer's *decision making unit* regarding the adoption of new products (table 5).

Good examples of generating and integrating customer knowledge and focusing on contact information were found in projects *Anti-resist*, *Foam*, and *Additive*. Within project *Anti-resist*, tire manufacturers were considered as customers for the product under development. Employees working on this project already had contacts at these tire manufacturers because *Anti-resist's* home organization already supplied yarn for tire reinforcement. However, it appeared that these contacts did not have the knowledge to work on par with the *Anti-resist* team. Then these existing contacts looked for other R&D groups in their company that were more familiar with the rolling resistance phenomenon and provided the *Anti-resist* team with contact information. Thus, project members were referred to new R&D contacts at existing customers. As the business manager involved in project *Anti-resist* explained: "*First we called our new product 'modified fibre' but we found out that the fibre people at our customer did not really understand our new product. These fibre people put us in contact with the materials group of their company that could better understand our new product.*" In contrast, team members in project *Foam* used existing contact information in the product development project: "*The reality is that customers who use our thermoplastics for injection moulding are potential customers for the foam form as well. So we know all about them and the contacts were already there.*" - Marketing manager *Foam*. In project *Additive*, team members could not use existing customer contact information for reference purposes or for direct collaboration. Because they did not have contact information of customers in the relevant market segment, they had to search for this information. The main knowledge generation practice used for this purpose was desk research. As the business manager involved in *Additive* explained: "*Initially it was paperwork...buy a market study on low molecular weight polymers and what plastics they are going into. Then you pinpoint the producers of these plastics and look on the internet if you can find contact information.*"

Next to contact information, knowledge

was generated on the customer's decision making unit regarding the adoption of new products. Also this knowledge was used in new product decision making. Good examples of generating and integrating customer information that focused on the customer's decision making unit are provided by projects *Heat*, *Green*, and *Diffuse*. In project *Heat*, project members were already familiar with the automotive 'under the bonnet' segment because the products of *Heat's* home organizations had been used in this segment for over a decade. They had contacts at several engine part manufacturers and automotive OEMs and used these to identify decision makers at these downstream parties. Subsequently, they were able to convince these decision makers to work with them on the project. By working together with epoxy resin manufacturers, project members involved in *Green* found out that decision makers in the aeronautics value chain wanted more tests than decision makers at customers in other value chains before they made the decision whether or not to adopt a new product. As the R&D manager involved in *Green* explained: "*We learned that some of our customers, for example in the aeronautics value chain, have longer qualification and decision processes than others.*" Using this information led to *Green* project members paying less attention to the aeronautics value chain and focusing on other value chains to speed up commercialization of the new product. If the application is both new for the product developing organization and the customer, as in the case of project *Diffuse*, and the development organization is not sure they are pursuing a significant opportunity, information on the decision making unit can bring some assurance: "*At the start [of the project] I visited this guy [at the customer]. His project was not really serious. He had a small laboratory and was working with students. However at a certain point in time I learned that this organization really wanted to commercialize this license plate system. At that time we could see it as a true development project.*" - Business developer *Diffuse*.

5 Discussion and Conclusions

In this study we offer a comprehensive and empirically derived framework of market knowledge as used in successful product innovation of firms operating in the chemical industry. This framework can be used for theoretical analysis as well as for practical purposes.

Based on a qualitative analysis of six innovation projects we agree with a group of scholars (Kusonoki et al., 1998; Turner and Makhiya, 2006; Winter, 1987; Zander and Kogut, 1995) that knowledge is a complex resource incorporating multiple dimensions linked to the decision situation at hand. Research in marketing and product development tends to see market knowledge as consisting of customer need knowledge and segment knowledge. The present study shows that this distinction ignores other important market knowledge dimensions. At least in the context of product innovation in the chemical industry four dimensions can be distinguished: *segment knowledge, application knowledge, product usage knowledge and customer knowledge*.

Segment knowledge is market knowledge on parts of the overall market environment, involving the aspects segment size, segment growth rate, and stakeholder behaviour. This market knowledge dimension has some precursors in the marketing and product innovation literature (see e.g. Adams et al., 1998; Jaworski and Kohli, 1996; Veldhuizen et al., 2006). Regarding the dimension of customer need knowledge as used in most of the marketing and product innovation literature our study suggests that it can be refined by adding the independent dimensions of application knowledge and product usage knowledge. This refinement can directly be linked to focusing our research on the chemical industry. The majority of scholarly inquiries in marketing, and also a lot of studies in product innovation, build on compiled empirical data from a variety of industries. These studies fail to capture the idiosyncratic nature of individual sectors. Products from the chemical industry are specific in several aspects (Musso, 2005). This specificity, presumably, impacts the importance of market knowledge dimensions in product innovation. For instance, products in the chemical industry come early in the value chain. They are often very versatile and can be used in far more different applications than end consumer products. While a washing machine can be used for washing clothes, a plastic resin, for instance, can often be used in applications ranging from plastics bags to skis back to vehicle parts. Therefore, the choice of application and the acquisition of appropriate application knowledge are far more prominent in product innovation in the chemical industry than in the development of consumer goods. Finally we identified customer knowledge which is about customer contact information and infor-

mation on the customer's decision making unit. This last knowledge dimension is seldom discussed in empirical studies in marketing and product innovation which include consumer products. Most probably due to two differences between consumer markets and business markets (Kotler, 2003). First, in business markets there is often a relatively closer relationship between buyers and sellers of new products. Second, in business markets typically more people from the buying organization influence the adoption of a new product. These two characteristics probably make customer knowledge far more relevant in business markets than in consumer markets.

The findings of this research can be used in both academic research and in practice. The framework of different market knowledge dimensions in product development of chemical firms can be used by scholarly researchers as stepping stone to identify additional characteristics of product innovation in this industry. For practice, the framework can be used as a guideline for designing product innovation and marketing strategies. Because of the relatively tacit nature of market knowledge and its distribution across functional departments such as sales, marketing, and application development (Webster, 2002; Workman, 1998), market knowledge often is less obvious and hard to identify. Our framework can help managers to map market knowledge resources and develop market knowledge typologies. Subsequently these typologies can be used as guideline for looking into the future. For instance, when developing strategies or reviewing initiatives that emerge bottom up, managers could classify innovation options by assessing the degree of fit with market knowledge resources that already reside in the firm. In doing so, it can be assessed what knowledge resources are already in place and 'only' have to be updated and what knowledge resources have to be developed from scratch. Subsequently, based on these insights, market knowledge needs can be mapped during the development of a new product and project implementation can be assessed. Finally, the framework can help to match innovation processes with innovation project characteristics in order to increase product innovation performance (see also Smits, 2010).

6 Suggestions for further research

This research can be extended into several directions. Since our study was retrospective

it might suffer from cognitive biases and impression management (Huber and Power, 1985). For instance, with retrospective studies there is a tendency to filter out events that do not fit or that render the innovation story less coherent (Poole et al., 2000). Although we took several measures to minimize these risks, additional research which includes real-time analyses may further reduce these. As proposed by Leonard-Barton (1990) such studies could combine retrospective results with real time product innovation cases to better observe the process as it unfolds. Additionally further research may want to test the effect of generating and integrating market knowledge on product innovation performance of chemical firms. Are some market knowledge dimensions more important than others, and do firms that focus on a wide variety of market knowledge are more successful than firms that take less market knowledge dimensions into account? Also, because our research focused on market segments and direct customers, further research could look further down the value chain and look into the relevance of value chain knowledge as being important for innovation. Finally, an obvious topic for further research might be to map other knowledge resources in product innovation of chemical firms such as, for instance, technological knowledge. Plausibly, a distinction between product and process technological knowledge could be found (Barnett and Clark, 1996; Pisano, 1997).

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