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Optimising NPD in SMEs: a best practice approach

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Abstract

Purpose – This study analyses new product development (NPD) processes of small- and medium-sized enterprises (SMEs). The purpose of this paper is to find successful innovation processes of SMEs on the one hand, and to reveal starting points to further improve these processes on the other.
Design/methodology/approach – Data were gathered from 49 semi-structured, face-to-face interviews with German firms. From the total of 49 cases, the authors identified three manufacturing SMEs with high-performing innovation processes, whose NPD processes the authors took as best practice examples. The authors then used the design structure matrix to map these three NPD processes, and optimised the sequence by applying an optimisation algorithm.
Findings – The authors determined which activities could be done sequentially, in parallel, or overlapping. The authors also scrutinised the position of dynamic milestones and demonstrated that the best-performing SMEs had flexible NPD processes, which allowed for an accelerated innovation process.
Research limitations/implications – Due to the qualitative design of the investigation, the research presented was not specifically designed to draw statistical generalisations. For this reason, the results may not be applicable to all SMEs.
Practical implications – The authors recommend that SMEs uncouple activities as much as possible. In this regard, the findings revealed that that especially technical and economic activities may be conducted in parallel due to their low dependence.
Originality/value – The paper offers an SME-specific NPD process to optimise the innovation performance. Moreover, the findings deliver new knowledge on how the best-performing SMEs innovate.
Keywords Innovation, Germany, Small- and medium-sized enterprises, New product development process, Design structure matrix
Paper type Research paper

Introduction

Small- and medium-sized enterprises (SMEs) are highly important for national economies. For instance, a total of 99 per cent of all enterprises operating in the European Union are SMEs (Muller *et al.*, 2014). These firms employ around 87 million people (Gagliardi *et al.*, 2013). In addition to economic significance as employers, many impressive innovations have come from newcomers and SMEs (Christensen, 2013). This means that SMEs make up an impressive proportion of employment, encourage innovation, and stimulate economic variety (Ayyagari *et al.*, 2007; Radas and Božić, 2009). However, despite their great micro- and macro-economic importance, in the contemporary world of business, rapid technological development, and changes in the business environment have intensified the pressure on SMEs. Short product life cycles, new product concepts and processes, and short reaction times to market changes (Gonçalves Silveira Fiates *et al.*, 2010) are just a few of the more prominent examples of

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why action in the field of new product development (NPD) is needed. What aggravates this situation is the fact that SMEs tend to have certain disadvantages: limited financial resources, scarce personnel capacities, and limited time to realise innovation projects (Laforet and Tann, 2006; Millward and Lewis, 2005). SMEs can survive this competitive environment and overcome their specific disadvantages through effective and efficient innovation management (Kamps, 2013; Laforet, 2010). Several approaches have been proposed in order to improve SMEs' innovation management, respectively, NPD as its core. For example, scholars emphasised the following instruments to advance NPD in SMEs: lean six sigma (Antony *et al.*, 2005; Kumar *et al.*, 2006); lean manufacturing system (Upadhye *et al.*, 2010); Kansei engineering (van Lottum *et al.*, 2006); quality function deployment (Kengpol, 2004); Kano model (Nejati, 2012); computer-aided innovation (Hüsig and Kohn, 2009; Kohn and Hüsig, 2006); total productive maintenance (Bamber *et al.*, 1999); and total quality management (Demirbag *et al.*, 2006; Salaheldin, 2009). Due to the range and diversity of these approaches, there is no universal approach to optimise NPD processes in SMEs.

Some studies argue that SMEs should imitate the best practices of NPD processes designed for large-scale enterprises (Scozzi *et al.*, 2005; Terziovski, 2010). However, it is questionable whether NPD processes that were developed and formalised for large-scale companies are transferable to SMEs. A number of studies have indicated that SMEs rarely use formalised process structures (March-Chordà *et al.*, 2002; Scozzi *et al.*, 2005). Although some studies have examined NPD process structures among SMEs (Berends *et al.*, 2014; DeToni and Nassimbeni, 2003; Huang *et al.*, 2002; March-Chordà *et al.*, 2002; Woodcock *et al.*, 2000), these studies have not focused on models that are generally accepted in SMEs. To our knowledge, no research related exclusively to the sequential optimisation of the innovation process in the best-performing SMEs has yet been conducted, meaning that our analysis makes a substantial contribution to the limited knowledge on this issue. The objective of the present study is to find successful innovation processes of SMEs on the one hand, and to reveal starting points to further improve these processes on the other. Building knowledge in this area will help SMEs to strengthen their ability to create innovative products, and therefore to optimise innovation management. Our paper is guided by the following research question:

RQ1. What characterises an optimised NPD process for SMEs?

The next section (Literature review) gives a theoretical overview of the NPD process and its development in SMEs. The third section (Method and data) describes the methodological approach and explains how we collected the empirical data. The fourth section (Results and discussion) presents and discusses the results of our study. Finally, in Conclusions and Implications, we summarise the results, highlight important theoretical and practical implications, and discuss the limitations of our study.

Literature review

Overview of NPD processes

The global corporate environment is becoming more and more complex, with many types of NPD processes continuing to exist in different forms (Rothwell, 1994). In light of this diversity of NPD processes, Verworn and Herstatt (2002) hold that there exists no universally accepted process model. However, while there are differences, there is a broad consensus that the sequences of an NPD process can be divided into idea generation, concept selection, development, and launch (Crawford and Di Benedetto, 2008; Salerno *et al.*, 2015; Ulrich and Eppinger, 2000). All NPD processes contain some elements of creating and choosing possibilities or ideas (Girotra *et al.*, 2010). This idea generation can be positioned as the key component at the beginning of the NPD process, an organisation that is often referred to as a "fuzzy front end" (Dahan and Hauser, 2002). This phase as one of the greatest opportunities for optimising the overall NPD process (Koen *et al.*, 2002), offering high potential to speed up the NPD process and to increase its performance (Cooper, 1999; Cooper and Kleinschmidt, 1994). During this phase, firms generate dozens, or hundreds, of alternative ideas for new products to identify the best opportunity (Girotra *et al.*, 2010). Firms may cooperate with different sources, such as customers, suppliers, employers, competitors, or other firm sectors to generate ideas (Sajid *et al.*, 2015).

Subsequently, firms usually evaluate and choose new product concepts (Crawford and Di Benedetto, 2008). The evaluation of these concepts is based on the probabilities that these new products will meet customer and stakeholder requirements, have sufficient financial impact, be successfully commercialised and implemented in the production process, and offer suitable product and market positioning – as well as additional external influences (Rainey, 2005). A careful evaluation is essential, because poor product concepts can lead to high costs and manufacturing delays, which can endanger successful commercialisation (Fung *et al.*, 2006). To ensure satisfactory evaluation, firms should integrate qualified personnel from different sectors. For example, engineers and technicians might work together in teams, or specialists in manufacturing processes might be included (Crawford and Di Benedetto, 2008). The selection of the final new product concept is based on the instincts and experience of the evaluators, which is why hard rules play only a minor role (Rainey, 2005).

Development can be another phase in NPD processes. This phase is characterised by a huge number of activities – sometimes thousands, or tens of thousands – most of which are interdependent (Anthony, 1996). The development phase is when the final new product concept is manifested in a physical product, sometimes referred to as a prototype (McDaniel, 2014). A prototype is designed to showcase only the important and significant elements of the new product, leaving out unnecessary details (Mohr *et al.*, 2009). During this phase, the developers conduct trials and tests to ensure that the prototypes are built as designed, and that they fulfil all customer requirements (Ribbens, 2000). Dialoguing with the customer can produce useful information, which can contribute to evaluating and improving the prototype (Hackos *et al.*, 1997). During the development phase, preparing for production and planning what resources would be required are also important. Against this background, a product plan is created to optimise the development team's effectiveness and to accelerate meeting the objectives of marketing and sales (Rafinejad, 2007).

Finally, launch is a common phase to complete the NPD process. This phase aims to commercialise the new product successfully into the market (Rainey, 2005). The full production and market launch can be combined in this step (Cooper, 1990), with the prototype mass-produced and offered for sale (McDaniel, 2014). Well-targeted marketing and selling activities are essential for a successful market release of the new product (Shavinina, 2003). Such activities include the completion of the marketing plan, the preparation of the launch plan, and the finalisation of extended product requirements (Thota and Munir, 2011).

In addition to being organised by key component activities, the individual phases of the NPD process can be separated by checkpoints (gates) or milestones. When the phases are separated in this way, the NPD processes are referred to as Stage-Gate®

NPD processes. According to Cooper (1994, 1996), these sequential phases (stages) represent a set of activities that maps the development of the new product from idea generation to market launch. Within each gate, a team of specialists (gatekeepers), such as engineers, technicians, or management personnel, make the decision as to whether they should continue with (go) or abort (kill) the innovation project. According to Litke and Kunow (2006), milestones are checkpoints for the responsible executives to decide to continue with or abort the project. In the modern understanding of NPD processes, innovation projects no longer move from gate to gate, but from milestone to milestone (Cooper, 2014). In this respect, milestones can be interpreted as gates and vice versa. The Stage-Gate® system is the most widespread and best known milestone-base system (Ettlie and Elsenbach, 2007; Shaw *et al.*, 2001): many large-scale companies have implemented this approach (Cooper, 2008, 2014; Cooper and Kleinschmidt, 1991; Whiteley *et al.*, 1998), and 75 per cent of top-performing companies use Stage-Gate® NPD processes (Cooper, 2014; Cooper and Edgett, 2012). The Stage-Gate® NPD process has evolved over time, moving from an inflexible phase-review approach without feedback loops or cross-stage iterations (Unger and Eppinger, 2009) to an approach with more flexibility and speed (Cooper, 2014).

NPD in SMEs

Following the pioneering work of Schumpeter (1939, 1942), the importance of innovation is undisputed. Innovation generation is not only necessary for large-scale companies, but also for SMEs (Freel, 2000a; De Jong and Vermeulen, 2006). However, Edwards *et al.* (2005) argue that, although a number of investigations have been undertaken in the area of innovation in SMEs, these studies have made only a marginal contribution to clarifying NPD processes in SMEs.

When thinking about SMEs, one must keep in mind that they are not simply scaled-down versions of large-scale companies (Welsh and White, 1981). For example, Olson *et al.* (1995) and Vossen (1998) found that SMEs have less bureaucracy, Hausman (2005) emphasised that SMEs are able to react faster to market changes, and Laforet and Tann (2006) highlighted the close customer relationships that are characteristic of SMEs. Such SME-specific characteristics help them to respond quickly to new circumstances and to exploit niche markets for products (Jenkins, 2006, 2009), making SMEs adaptable and flexible and able to endure changing conditions. While these distinguishing features may influence NPD process activities, all of them apply to the firm level, rather than to specific NPD process characteristics. However, since our objective is to identify the characteristics of an optimised NPD process for SMEs, the previous findings on NPD processes of SMEs must also be reviewed.

It is assumed that SMEs base their practices on experience (Scott *et al.*, 1996), and that they tend to focus on specific activities, such as engineering tasks, and neglect others, such as marketing activities (Huang *et al.*, 2002). Although screening and research activities are relevant indicators in examining the market environment in structured NPD processes in large-scale companies (Cooper, 1983; Cooper and Kleinschmidt, 1986), previous studies on SMEs found these activities to be minimally present (Hoffman *et al.*, 1998; Moultrie *et al.*, 2007; Scozzi *et al.*, 2005). The formality of the NPD process is an important resource for successful development, and can have a positive influence on the global NPD process outcome (Kleinschmidt *et al.*, 2007). While the formal content of product innovation is part of NPD processes for top-performing large-scale companies (Barczak *et al.*, 2009; Kahn *et al.*, 2006), the findings of March-Chordà *et al.* (2002) and Scozzi *et al.* (2005) revealed that SMEs rarely use formalised NPD processes for creating new products. Further, while recent studies have advocated approaching NPD processes as a group of overlapping activities performed at the same time and having cross-functional interactions (Barczak *et al.*, 2009), DeToni and Nassimbeni (2003) reported that the SMEs in their study had weak connections and little overlap between activities. This lack of simultaneous engineering can cause the NPD process to lose speed, ultimately requiring more time to get the new product on the market (Singh and Lewis, 1997). From the standpoint of marginal contribution in the clarification of NPD processes in SMEs, it is unclear whether SMEs follow certain phases with their NPD processes, and whether they rely on specific gates and milestones to monitor their process activities.

According to Ledwith (2000), the main difference between larger organisations and smaller firms is their expenditures on process improvements. In a study of 36 Irish electronics firms, Ledwith found that larger firms expended proportionally more than of their turnover on process enhancements as compared to SMEs. Optimising process performance is essential for SMEs (Wolff and Pett, 2006), and is a key driver of their innovativeness (Laforet and Tann, 2006). Since SMEs' biggest collective problem is their limited resources (Deakins and Hussain, 1994; Freel, 2000b; Hausman, 2005; Pitta, 2008; Rothwell and Dodgson, 1994; Sivadas and Dwyer, 2000; Verhees and Meulenberg, 2004), SMEs have additional incentives to operate efficiently and avoid unnecessary tasks.

To sum up, while it may be reasonable for SMEs to find the right innovation process by trial and error at the beginning of their entrepreneurial activity, as the number of projects and the strength of the competition grows, structured innovation processes become a necessity (Pitta, 2008). The present study is therefore an important step in increasing the performance of the NPD processes of SMEs, so as to overcome the disadvantage of their limited resources.

Methods and data

Type of study

In order to answer our research question, we employed a qualitative research design. This design was chosen for two reasons. First, up to now there has been only a limited number of studies tackling the issue of NPD processes in SMEs. More specifically, as we focus on complex interactions within the NPD processes, the qualitative method is more suitable than quantitative procedures (Carson *et al.*, 2001). Second, qualitative data enable us to scrutinise the best-performing NPD processes. This juxtaposition of process structures with the best in industry is in fact a reasonable approach for SMEs to sustain their competitive advantages (Cassell *et al.*, 2001; Singh *et al.*, 2008).

Data collection and measurement

Our data rely on 49 semi-structured, face-to-face interviews between August and October 2013. We visited all firms on-site, which is in accordance with Gelo *et al.*'s (2008) argument that natural environments support qualitative data collection. We recorded and subsequently transcribed every interview. Following the suggestions of Yin (2013), protocols and the creation of a case study database reinforced the reliability of our research. The subjects were selected on the basis of business directories. A telephone guideline was applied to verify that the firms were SMEs. In order to ensure that every firm operated under similar economic circumstances and under equal law, we focused our interviews on the Federal State of Thüringen, Germany. SMEs are in fact of utmost importance for this country as approximately 60 per cent of all employed people in Germany work for SMEs (Dreher and Körner, 2014). All phone calls served to arrange personal interviews with employees working in innovation-oriented positions. Moreover, we implemented the key informant approach of Kumar *et al.* (1993) by conducting interviews with employees or CEOs who were deeply involved in the innovation projects of their firms.

In our survey, we used blank cards and a bar graph (see Figure 1) to capture the structure of the NPD processes. During this procedure, the key informants were asked to record each activity of their firm's NPD process on one card, and then to place these cards in the order in which the activities are realised. After documenting the NPD process by the key informant, we transferred this process structure into the bar graph. The bar graph, shown by Figure 1, allows identifying parallel and overlapping activities in the NPD process. In addition, we registered the position and number of milestones, and the positions at which activities were iterated (feedback loops).

Comparability of cases

We aligned our case selection to the SME determinations of the European Union, which means that all cases had fewer than 250 employees and either less than or equal to 50 million euros in annual turnover or less than or equal to 43 million euros in their total balance sheet (European Commission, 2003).

Although we concentrated our research on technology-based SMEs in order to guarantee the comparability of results, important aspects such as main business sectors, innovative product groups, and customer focus could be identified only in the aftermath of the interviews. As a result, we filtered the 49 cross-industry cases by their business sectors. We built our industry filter on the NACE code system. In this regard, we strongly focused in accordance with our research question on manufacturing SMEs, meaning that all analysed cases fall in the same NACE class (NACE class C). Specifically, we gained 18 comparable firms from which three firms were engaged in metal fabricates (NACE class 25xx), 13 in electronics or optics (NACE class 26xx), and two in electrical equipment (NACE class 27xx). Table I describes the 18 manufacturing SMEs in more detail.

Moreover, since we aimed at finding characteristics of an optimised NPD process for SMEs, we used an additional filter variable to identify the most innovative firms among the 18 cases which were correspondingly successful in their overall innovation performance. In our definition, innovation performance is high when the percentage of sales with new products is more than or equal to 50 per cent of the annual turnover. We ended up with three top innovators from our cases. The firm characterisations in Table II were derived by using triangulation with data from commercial registers, websites, and interview transcripts. It is noteworthy that all three cases were not only the best innovators among the 18 firms but also successful in their general firm success with regard to their returns on equity.

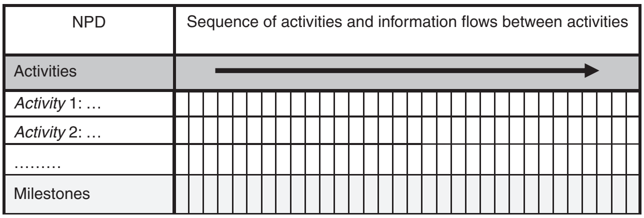


Figure 1.
Bar graph and components used in the questionnaire

Table I. Characterisation of the firms

ID	Proportion of turnover with new products in %	Return on equity in %	Sales in thousand euros	Customers	Employees	Founding year
M1[a]	10	16.05	20,000	4,800	110	1996
M2	25	6.56	14,100	350	100	1991
M3	20	−4.61	15,000	55	150	1941
M4	8	−21.63	2,000	165	18	1994
M5	35	3.45	9,700	35	125	2005
M6	30	24.72		200	16	1990
M7	5	20.25	2,300	38	15	1991
M8	25	64.38	1,500	50	15	2005
M9	23	8.07	1,000	200	17	1992
M10	15	5.18	450	25	7	1994
M11	50	20.18	700	30	12	2005
M12	90	24.12	800	70	10	2008
M13	8	41.69	900	25	9	2011
M14	25	18.66	14,100	200	95	1992
M15	15	4.29	20,000	50	137	1962
M16	30	18.24	8,000	160	91	1992
M17	40	2.92	3,800	200	40	1991
M18	100	39.68	1,000	18	12	2010

Note: [a]M1, Manufacturing SME 1

Coding procedure and data analysis

Due to the type of data we gained from the interviews and the limited state of knowledge in terms of SME-specific NPD processes, we focused on qualitative methods to analyse our data. In contrast to the classic coding procedure where the researcher interprets transcriptions and recordings to build codes (e.g. Flick, 2014; Yin, 2013), we matched the interview data that described the NPD processes of the three cases with 20 categories derived from Cooper (1983). These categories are based on research in 58 R&D projects and served us to find practical-oriented categorisations for the NPD process activities in our study. Similar to what is known as inter-coder agreement, we conducted two independent matchings and merged the results afterwards to increase the reliability of our study (Miles *et al.*, 2014; Silverman, 2008). A matching example of this kind is illustrated in Table III for a better understanding.

Design structure matrix (DSM)

It has become accepted that reducing the lead time of NPD processes enhances the customer value (Browning, 2000). A popular approach to analyse as well as to optimise such processes is the DSM (Yassine *et al.*, 1999). First applications of this method in project management can be traced back to 1960 (Browning, 1998, 2001). Recent applications of the DSM underline its relevance. In this respect, Chen *et al.* (2003) showed an approach how R&D projects can be rescheduled with DSMs. Danilovic and Browning (2007) extended the DSM logic to ascertain different domains of the firm simultaneously, Pektaş and Pultar (2006) deployed a parameter-oriented DSM for the architectural design process and Kratzer *et al.* (2008) applied DSMs to investigate networks in NPD collaborations. Furthermore, Nepal *et al.* (2011) utilised the DSM to implement the ideas of the Lean Thinking to NPD processes and (Cho and Eppinger, 2005)

ID	M11[a]	M12	M18
General aspects			
Date of foundation	2005	2008	2010
Business sector	Manufacturing	Manufacturing	Manufacturing
No. of employees	12	10	12
No. of customers	30	70	18
Innovative product groups	Passive wireless sensor systems, wireless data transmission of break discs	Magnetic measurement systems	Industrial image processing, computer-aided quality assurance
B2B vs B2C focus	B2B	B2B	B2B
Main markets	Germany	Worldwide	Germany
Return on equity in %	20.18	24.12	39.68
Interview aspects			
Length of interview	90 minutes	40 minutes	60 minutes
Interviewee	CEO	CEO	Authorised representative
Innovation key figures			
Turnover 2012	700,000 EUR	800,000 EUR	1,000,000 EUR
No. of product development projects	4	6	4
Proportion of turnover with new products in %	50	90	100
Methods applied by cases			
Idea generation	Brainstorming, media research, research of patents and competitors, visit of fairs and conferences	Experience of long-term employees	Discussion groups, research
Concept selection	Cost estimations, review of feasibility, ordering of discussions	Discussion groups	Experience of long-term employees, simulations, tests
Voice of customer	Customer integration by customer orders, first customer discussions at the beginning of the NPD process, customer receives interim results, customers will be invited after new test results	Presentation of NPDs on fairs and conferences, persuasion of the customer to test new products, Bet-customers with better support and opportunities for customising In case of customer orders: customers will be integrated from the beginning	Meeting with customer, presentations, continuous reporting and demonstrations, continuous customer integration at every meeting, flexible approach without predefined dates

Note: [a]M1, Manufacturing SME 1

Table II. Characterisation of the best-performing innovators

captured information flows in complex design projects. However, as already stated in the introduction of this paper, SME-specific research in this field is still very limited, which reveals the research gap we are aiming to fill.

In general, a DSM can be used to examine distinctive dimensions such as team organisations, necessary components, or development activities (Browning, 2001).

For the purpose of this paper, the activity-based DSMs are the relevant ones. Applying a DSM reveals opportunities of decreasing the process lead time (Browning, 1998). This provides the opportunity to find a specific ordering of activities that leads to an improved process flow. Once a task requires input from an activity which has not yet been performed, waste may occur in terms of rework or waiting times (Browning, 1998).

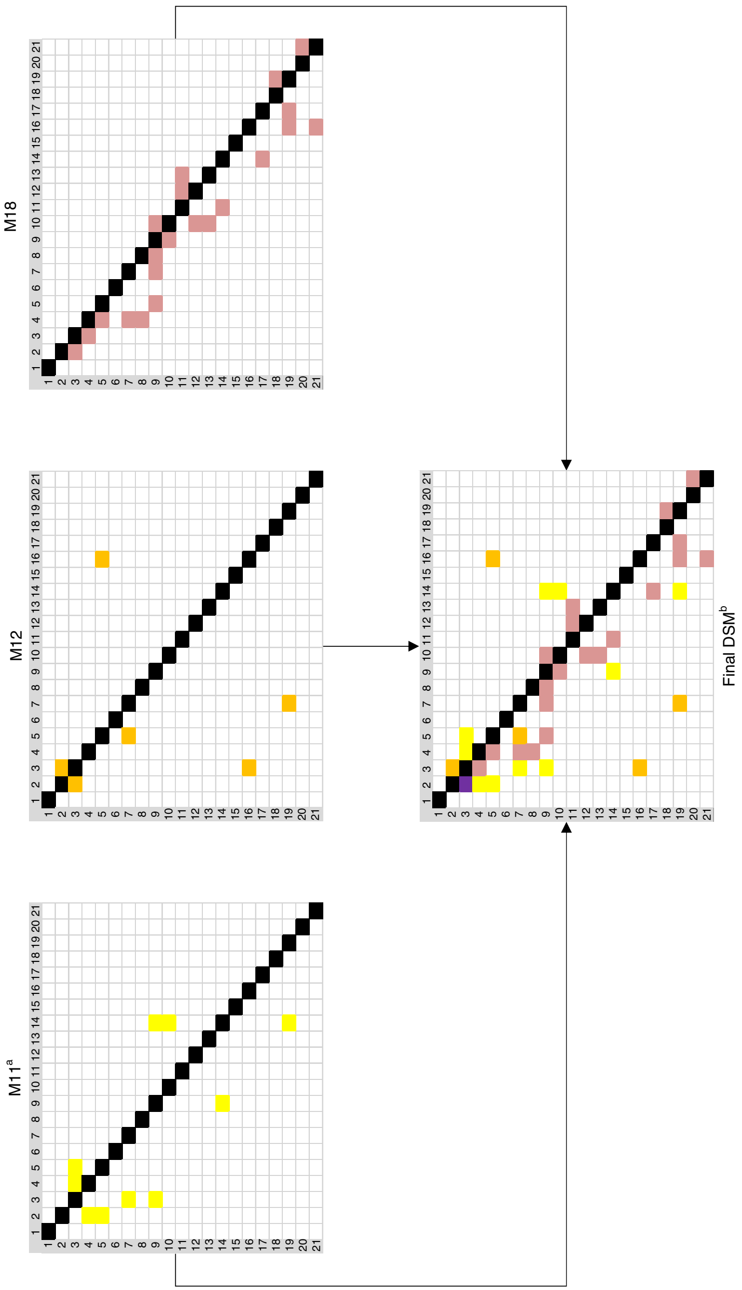
A great advantage of DSMs is that they inform about dependencies between activities (Ahmed *et al.*, 2007; Browning, 1998). In fact, DSMs are useful to organise the development process and to see where activities belong to, from where they receive their information, and to where they forward information (Abdelsalam and Bao, 2006). The specific power of DSMs lies in their abilities to highlight time-critical tasks (Browning, 1998), which is why DSMs are from the managerial perspective important to identify opportunities for improvements.

We followed the three-step approach suggested by Browning (2001) to deploy an activity-based DSM. Therefore, we first broke down the NPD process into individual activities. We accomplished this by asking the interviewees to name all relevant activities in their NPD process. Second, we identified the relations between these activities by asking the respondents in which chronology they normally perform these development activities and whether there are any feedback loops or parallel activities. As previously stated, we matched these activities with those derived from Cooper (1983) to be able to compare the three processes. After we created an individual matrix for each process, we unified all three to a final DSM. This procedure is illustrated in Figure 2 and reflects an approach to find the categorisations that were necessary to describe the NPD processes of all three investigated top innovators. Colourings in yellow, orange, and red indicate information dependencies between activities of the individual processes analysed. In the final DSM, the three different colours display propinquity of the processes, whereas an overlapping between M12 and M18 is highlighted in purple. Because this study is based on a qualitative design with a rather limited number of cases, we decided to only exclude those categorisations from the final DSM that played no role in all processes.

Furthermore, we analysed the potential reintegration of activities by applying the optimisation algorithm of the Cambridge Advanced Modeller (Wynn *et al.*, 2010). On this account, we reordered the activities. This procedure is also known as sequencing (Danilovic and Browning, 2007) or partitioning (Yassine, 2004). Feedback marks can be avoided through this method. If the avoidance may not be successful, the subordinate aim becomes then to bring these marks as close as possible to the

Table III. Example of data matching with Cooper's (1983) NPD process categorisations

Categorisations derived from Cooper (1983)	Excerpts of transcripts/recordings
Market-derived idea generation	"At the beginning of idea generation is always the customer pitch. The customer comes up with a problem and he wants to know how this problem could be solved" (M12) "We've got the customer query at the beginning" (M18)
Market launch	"The product goes to the customer after tests and evaluations. If everything is fine, the project will be closed and we will sell the product" (M18) "After the second revision, the product is ready to go to the customer" (M11)



Notes: [a]M1, Manufacturing SME 1; [b]Design structure matrix

Figure 2.
Design structure matrix unification procedure

diagonal (Browning, 1998; Yassine, 2004). Tasks would therefore not need to jump over long distances in the process, which decreases the overall process lead time. Finally, we banded the DSM to illustrate independent activities that can be performed in parallel (Danilovic and Browning, 2007; Yassine, 2004).

Tearing is known as a method to further optimise the process by simply eliminating feedback loops based on certain assumptions (Yassine, 2004). However, this process is very subjectively related. For this reason we decided not to apply this method to our model. Instead, we followed the proposal of Elezi *et al.* (2010) by reviewing the final matrix in terms of its plausibility. This procedure is important to ensure that sequential activities in the matrix are in line with the operational reality of NPD processes, meaning that idea generation is unlikely to be a downstream activity of the market launch, for example. We applied pattern matching by comparing our results with the ones we gained from the literature review (Eisenhardt and Graebner, 2007; Yin, 2013).

Results and discussion

Following the matching procedure explained in the methodology part, we eliminated the activities that were not necessary to describe the NPD processes of the three top innovators. As a result, we identified 17 NPD process activities altogether. On this account, market research, technical derived idea generation, test of marketing, and revision of launch plan were removed from Cooper's (1983) list. In contrast to this, two processes included the optimisation of the product, which had not been envisaged by Cooper (1983). Therefore, we added this to the list to be able to adequately plot the processes.

Since a DSM is capable of illustrating information exchanges between activities, it is possible to indicate after the DSM optimisation which activities are independent from each other. Because these activities do not have to wait for information to be received, they can be performed in parallel (Browning, 1998). This fact is important since parallel activities support shorter cycle times, which are advantageous for new product performance (Chen *et al.*, 2005; Jayaram and Narasimhan, 2007). Figure 3 illustrates the result of the process optimisation. Marks below the diagonal indicate that information is transferred to downstream tasks (Yassine, 2004). Analogously, marks above the

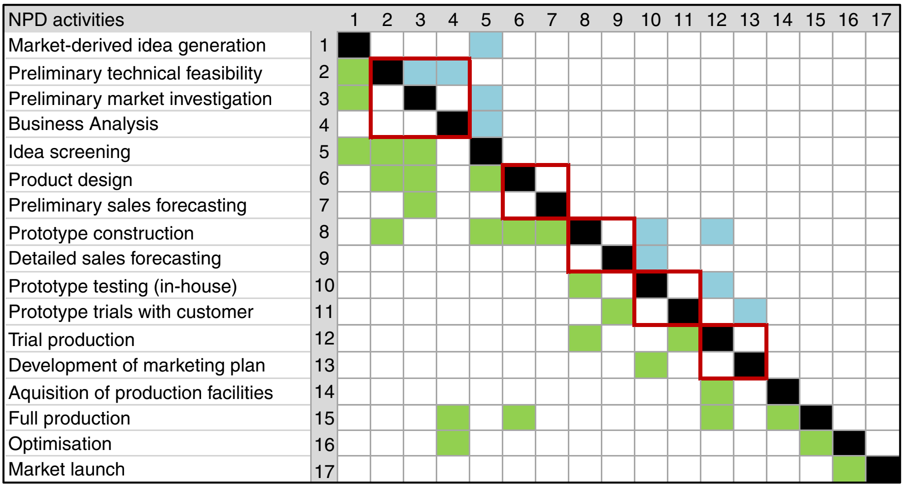


Figure 3.
Optimised design structure matrix after partitioning and banding

diagonal point to feedback loops which may cause rework (Browning, 1998, 2001). All potential feedback loops are highlighted in blue. The information transfer to downstream tasks is marked in green. Moreover, the red squares denote the result of the banding procedure. The interpretation of a DSM is based on the columns and rows in the matrix. The columns show where information is forwarded to; where an activity receives its information from can be inferred from the rows.

According to Tang *et al.* (2000) and Yassine (2004), there are three basic types of relations between activities:

(1) uncoupled activities, where a parallel execution is possible;

(2) activities that need to be performed in a sequence; and

(3) coupled activities where Activity 1 forwards information to Activity 2 and receives information back from Activity 2.

All of these relations can be seen in the final DSM. Essentially, every activity within a band is independent from other tasks in the same band. Taking this into account while executing the NPD process, project managers know exactly which activities can be performed simultaneously due to their independence. The first four activities in the DSM illustrate an example. While both the preliminary technical feasibility study and the preliminary market investigation receive information from the market-derived idea generation, these activities depend on each other. In contrast to this, the three activities following the market-derived idea generation do not share any information amongst themselves, which is likewise the reason why they belong to one band and can be executed in parallel. Interestingly, between the second and fifth band, it can be seen that the independent activities within each band also belong to different divisions, meaning that technical and economic tasks run simultaneously. Noteworthy is that the banding procedure disregards all feedback loops (Yassine, 2004).

Sequential activities are coloured in green in Figure 3. Interpreting this, the matrix shows that after idea generation is accomplished this activity forwards information to the preliminary technical feasibility, to the preliminary market investigation as well as to idea screening. Moreover, it emerges that idea generation has a feedback loop to the beginning of the process, meaning that both activities are coupled and exchange information in both directions. Again: feedback loops are generally unintended. We developed an optimised DSM by involving the information we gained from the three cases. However, every firm applying this process should rethink whether it is really necessary to have coupled tasks or not. From our point of view, it might be possible to forward all information required from idea generation to idea screening without the necessity to look back for more information. On this basis, the optimised process highlights specific information exchanges which could be time-critical to the process (Browning, 1998).

One may argue that our analysis neglects the probabilities that certain activities actually occur in the NPD process of SMEs. However, we optimised all those activities which represented the NPD processes of the three top innovators. In operational practice, it may be reasonable for firms to eliminate those activities that do not play a role in their processes without changing the full process in detail.

Our process model for best-performing SMEs follows the general content of NPD processes. One key similarity is that NPD starts with idea generation instead of concept selection, followed by development and, finally, launch. We found that idea generation is strongly customer-driven. Even though the three best-performing SMEs in our study mentioned ordinary methods applied for idea generation such as brainstorming, media research or discussion groups, we found that for the most part, ideas derived from customer inquiries. In fact, the SMEs substantiated how important voice of customer (VoC) was for their NPD processes: all of the three cases made high efforts to integrate the customer by means of continuous presentations, meetings or even less common approaches, as for instance special offers for beta-testers and reports on interim results. The early involvement of the customer in idea generation is especially important for SMEs (Laforet and Tann, 2006). For all three SMEs, the customer approached the SME needing a solution for a specific problem. Contrary to Girotra *et al.*'s (2010) finding that firms generate many ideas, the SMEs in our study tended to have limited idea creation, which was led instead by customers. What is also worth mentioning, Cooper *et al.* (2004) emphasised that NPD best-performers handle VoC far more proficient than their less successful counterparts. Our study supports this suggestion by underlining the important role of customer involvement in the NPD process.

After defining the problem, SMEs search for ways to address it, and evaluate the best possible new product. In our case study, the SMEs combined their expertise with market information to determine the ideal product. These SMEs also included resource planning in their business analyses, as resources must be appropriately allocated for improving product development (Rothwell, 1972). We found that examinations of technical feasibility, market investigation, and business analysis could all be uncoupled, meaning that these three steps could be carried out sequentially or in parallel. According to DeToni and Nassimbeni (2003), SMEs usually use a sequential organisation for innovation, despite the fact that SMEs – after guaranteeing sufficient resources – could accelerate their NPD processes by instead completing these activities more simultaneously (Singh and Lewis, 1997). Together, all of these activities serve to screen ideas, so as to select the best concept for new product generation by methods such as cost estimations, discussion groups, and simulations.

Once a concept has been identified, SMEs move on to product development. Our analyses identified the most frequent activities of the entire NPD process. While Anthony (1996) argued that the majority of these activities are coupled and dependent on each other, this did not match our findings. Instead, we identified four activity bundles related to conceptual activities (each containing two activities) that can be uncoupled or independent. As already described in the previous step of concept selection, within these activity bundles, SMEs can develop new products either sequentially or simultaneously, potentially saving development time. We found that the best-performing SMEs work with prototypes before producing the new product. To ensure that all customer requirements were fulfilled (Ribbens, 2000), all of the SMEs in our study produced prototypes that could be tested and evaluated, both by the firms themselves and by the customers. According to Hackos *et al.* (1997), customer feedback can help to improve the prototype, helping to ensure that SMEs fulfil customer requirements. Once again, it should be noted that for the SMEs subject to our study, VoC plays a crucial role within their NPD processes. We also found that SMEs collected information to better plan the product itself as well as production, distribution, and market launch. Rafinejad (2007) confirmed that collecting information in this way optimises both commercialisation and development teams' effectiveness.

In the last step, the SMEs studied undertake minor adjustments and deliver the finished product to the customer. Unlike McDaniel's (2014) finding that final prototypes should be produced for a large number of products in mass markets, our best-performing SMEs did not do so. This was not a surprising finding, as SMEs have a reputation for operating in niche markets with a lower number of products (Jenkins, 2006, 2009), offering individual solutions for their customers, instead of exploiting mass-market opportunities. For SMEs, a four-phase innovation process should not constitute dogma, as it would artificially limit the NPD process. Indeed, in our three best practice examples, the NPD processes instead followed the flow of information between the NPD process activities.

In addition to comparing the general content of NPD processes, we identified potential feedback loops (Figure 3, blue squares). These blue squares signal that iterations are possible in two areas: between idea generation and idea screening, and between prototype construction and marketing plan. For both of these potential areas of iteration, we identified milestones in all of our three test cases. This indicates that the best-performing SMEs adopt Stage-Gate® NPD processes. However, such static gates are an artificial interruption of the NPD process; the relevance of these gates has decreased, and dynamic guidelines have come to replace concrete recommendations (Cooper, 2008, 2014). These dynamic guidelines allow the innovation project to be aborted or redirected at any milestone without interrupting the NPD process (Cooper, 2014). We therefore recommend placing dynamic milestones within both the areas stated above, to best monitor and assess the current status of the innovation project.

Regarding the actions related to the milestones, gatekeepers can provide oversight regarding the state of development, and can decide whether information from upstream activities is necessary. If product development continues as planned, feedback loops or iterations to previous activities are redundant, and only slow down the speed of the NPD process. The gatekeeper groups of our best-performing SMEs mostly consisted of the CEO, customer, and divisional director. Groups like this minimise the risk of poor decision making, which is more likely than in the case of an individual decision maker. The information resulting from completed activities (e.g. market-derived idea generation, preliminary technical feasibility, preliminary market investigation, business analyses, and idea screening) are collected, described and compared by the innovation project team (gatekeepers). In this sense, the project team makes a go decision and transfers the innovation project to downstream NPD activities. In case that "hard" criteria (e.g. the innovation project exceeds the accounting plan) are not satisfied, the project team makes a kill decision. In another scenario where "soft" criteria (e.g. the innovation project does not have sufficient quality) are not fulfilled, the project team decides that the project makes a feedback loop to previous activities. Furthermore, there could be negative external issues responsible for cutbacks in crucial NPD resources, which is why the project team would make a hold decision.

Conclusion and implications

In the present study, we interviewed NPD processes for 49 SMEs and analysed three SMEs with outstanding innovation and corporate performance. These three SMEs then served as best practice examples. We used the DSM to map these three NPD processes, and optimised their sequences. We found that our best-performing SMEs innovated in a general sequence of four phases: idea generation, concept selection, development, and launch. These three SMEs had dynamic milestones in two areas of feedback loops, which kept the NPD process moving quickly. In addition to identifying the existence of milestones, we found the general sequence of NPD processes to be formal and structured in the three cases. Kleinschmidt *et al.* (2007) hold that this formality can have a positive influence on innovation success in SMEs. In contrast to common models of the NPD process, our paper has been the first to demonstrate that SMEs can conduct different NPD process activities sequentially, overlapping, or in parallel. We also identified in which areas dynamic milestones can be placed. Referring to our research question, we therefore found that an optimised innovation sequence for SMEs consists of a mix of both sequential and parallel activities, as a new product moves from idea generation to market launch. The flow of information between these activities was a decisive factor in optimal innovation sequencing.

The results of our study have important implications for both theory and practice. To our knowledge, the present paper is the first to demonstrate an optimised innovation sequence for SMEs. Considering the limited research that has been conducted in this field, our results are the foundation for further quantitative and qualitative exploration and replication. Based on our results, we form research propositions which need to be further investigated. First, the implementation of our optimised NPD process supports the decreasing of the process lead time. Second, the innovation success can be improved by applying the optimised NPD process. It is our hope that SMEs will implement the NPD process that we identified as having a positive impact on innovation success. Third, subsequent studies should investigate the relationship of the resource allocation in connection with coupled and uncoupled activities.

We found that the best-performing SMEs followed NPD processes which correspond to the Stage-Gate® system. More specifically, the DSM revealed a new NPD process being optimised in terms of cycle time and customer integration. While this process starts with idea generation, which is mainly a result of strong customer involvement since the best practice examples investigated in this study made high efforts to integrate the customer in their processes, it will move on to the concept selection in Phase 2. Here, technical feasibility analysis, market investigation as well as business analyses can be performed parallel in order to decrease cycle time. Phase 3 concerns the product development. The ability to perform parallel tasks in this stage rests upon low dependencies between technical and economic activities. On this account, product design can be accomplished together with preliminary sales forecasting, prototype construction along with detailed sales forecasting, internal prototype tests with external tests involving customers, and the trail production together with the marketing plan. In the last stage, full production, product optimisation, and market launch depend on each other and will thus follow sequential procedures. Such an NPD process can have a positive influence on the time required to bring a new product to market. This optimised innovation sequence saves resources by preventing unnecessary work. What is more, we demonstrated that the DSM can actually be used to analyse and optimise NPD processes of manufacturing SMEs. Indeed, the DSM turned out to be an excellent tool to illustrate information flows and dependencies and independencies between specific NPD process activities.

With regard to practical implications, if our research propositions are correct, SMEs should adapt our optimised NPD process in the generation of new products. Moreover, we recommend that SMEs uncouple activities as much as possible: reworking NPD processes to allow activities to overlap or to be completed simultaneously will reduce development time by allowing development teams to consider the amount of resources that may be required later on. Our results revealed that especially technical and economic activities may be conducted in parallel due to their low dependence. Therefore, we suggest that SMEs aiming at improving their NPD processes should start by evaluating whether these activities can be performed simultaneously. Milestones that we identified as potential feedback loops should also be placed dynamically. This dynamic milestone placement prevents unnecessary delays in the NPD process. At these milestones, the target performance of the new product can be assessed by the CEO, customer, and divisional director. The committee can decide at these points whether information from additional upstream activities is necessary, or whether the process can flow as planned. As we identified that the best innovators in our study performed their NPD processes within the four domains of idea generation, concept selection, development, and launch, and dynamic milestones were used in areas which were highly information dependent, we claim that SMEs should adapt this approach from best practice. The orientation towards the best in industry may be a reasonable way to strengthen the NPD capabilities of SMEs. Finally, our study sets a cornerstone towards understanding the customer role within NPD processes of SMEs. The best practice cases showed that a strong consideration of VoC should be imperatively followed by SMEs in every phase of their NPD processes.

Due to the qualitative design of our investigation, the three best practice SMEs were drawn entirely from the German federal state of Thüringen. Thus, a notable limitation of our study is that our findings may not be applicable to other geographical areas. Furthermore, all three of the best practice SMEs came from the manufacturing industry, meaning that our results may not apply to other branches. The three firms were also rather small (ten to 12 employees), making the transferability of findings to medium-sized enterprises questionable. Furthermore, our survey focuses on the Stage-Gate® system for optimising NPD. It is conceivable that other optimisation approaches (e.g. quality function deployment, Kano model) could be beneficial to SMEs as well. In light of these limitations, we advise readers to interpret our findings cautiously. Nevertheless, this study offers an SME-specific NPD process to improve innovation performance. Moreover, it provides an essential contribution to the knowledge about how best-performing SMEs innovate.

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Further reading

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