Research Paper

Structuring and managing the new product development process – review on the evolution of the Stage-Gate® process

Tim Smolnik* and Thorsten Bergmann**

* Institute of Business Administration at the Department of Chemistry and Pharmacy, Westfälische Wilhelms-Universität Münster, tim.smolnik@uni-muenster.de.

** Institute of Business Administration at the Department of Chemistry and Pharmacy, Westfälische Wilhelms-Universität Münster and Center for Industry and Sustainability (ZIN), Provadis School of International Management and Technology, Industriepark Höchst, Building B852, 65926 Frankfurt am Main, Germany, thorsten.bergmann@uni-muenster.de

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Cooper introduced the *Stage-Gate®* process to structure the new product development (NPD) process in the late 1980s. Empirical evidence showed that successfully managing the NPD process helps firms to outperform their competitors over long periods of time. This indicates that appropriately managing the NPD process has become an imperative for firms. While some firms possess these capabilities succeed, many other firms lack the knowledge how to appropriately design and implement NPD processes. The NPD process must be flexible and adapted to changing market and customer requirements. Consequently, an efficient, less complex, and adaptive NPD process ensures not only a firm´s continuance but differentiates between winners and losers. For this reason, best performing firms are reinventing their NPD processes by adding elements of adaptivity, agility and acceleration to the original *Stage-Gate®* process, which represents a rather rigid framework. Novel approaches for the NPD process adaption have mainly emerged from literature and thus, still lack empirical evidence. However, some firms have already incorporated these elements in their NPD process. Therefore, the example of the *I2P3®* process is used to illustrate how a *Stage-Gate®* process can be adapted to the changing environment of the chemical industry. This article uniquely provides an overview of the evolution and advancements of different *Stage-Gate®* models and future research areas. In addition, it gives assistance for practitioners to select the right approach for their NPD process.

1 Introduction

Daubenfeld et al. (2014) showed in a survey that especially larger chemical companies use a *Stage-Gate®* process in new product development (NPD). The adaption and acceleration of the NPD process plays a crucial role for the chemical industry, since the chemical industry is currently facing ever-increasing competitive pressure. This increasing competitive pressure is driven by the globalization of value chains, shorter product life cycles, faster commoditization of products, and shareholder's expectations of publicly listed companies (CHEMonitor, 2014; Roland Berger, 2014; Daubenfeld et al., 2014). Thus, the NPD process must be custom-tailored for the respective industrial sector. Additionally, the high customer diversity, especially in the B2B sector, enforces high pressure on the innovativeness of chemical firms.

Therefore, the present article focuses on NPD processes, which are defined as actions, activities, and well-founded decisions which culminate in succeeding with the development of new products (Krishnan and Ulrich, 2001). Thus, NPD processes are described in literature as development processes comprising a linear system and as a lock-step process full of mandatory activities and actions (Cooper, 2008; Jespersen, 2012). Additionally, the goal of each NPD process is to separate high-potential inventions from losing ideas, reducing managerial uncertainty, and identifying areas where additional attention and resources are necessary to succeed in NPD (Hart et al., 2003). Concurrently, NPD processes ensure a strong strategic decision-making process of the firm by supporting management to develop and deploy the accurate competencies and resources across the NPD exertion (Bossink, 2002; Hart et al., 2003; Schilling and Hill, 1998). The most common way to organize and steer NPD processes is implementing stages and gates (Cooper, 2008). Therefore, Cooper (1990) introduced the concept of *Stage-Gate®* processes, which has become the basis of the majority of current NPD processes used in industry (Acur et al., 2012; Lewis, 2001). In the following sections, the original *Stage-Gate®* process from Cooper will be explained firstly. Subsequently, its evolution and advancements will be presented and discussed. At the end of the article, implications for practitioners and future research areas will be given.

Besides, the example of the *I2P3®* process from the Evonik Creavis GmbH, which is the central innovation unit of Evonik - a specialty chemicals company - will be presented to demonstrate how chemical companies can adapt their NPD processes to successfully develop new products to encounter changing market conditions and increasing competitive pressure.

2 Structuring the NPD process: The *Stage-Gate®* system

The ongoing management´s desire to reorganize the NPD process, to increase the product success rate, and to minimize the product development time culminates in an unending endeavor (Cooper and Kleinschmidt, 1995). Moreover, the continuous development of new products is a crucial success factor ensuring a sustained firm performance (Blundell et al., 1999). For instance, new products should balance expiring patents. However, while the development of new products is fundamental to guarantee a firm´s successful future, many empirical studies emphasize the high failure rate in NPD (Crawford, 1987). Cooper et al. (2004) benchmarked this difficult ambidexterity by opposing the immense benefits and the high risks in NPD. Thus, a significant difference between top performers and bottom players has been identified (cf. Table 1).

While companies being successful at new NPD belong to the 20% of the top businesses, companies failing with their NPD process stagnate within the bottom 20%. Although the average success rate for commercially successful projects values respectable 60.2%, the significant disparity of the top and bottom 20% of businesses poses the question: *What distinguishes winners and losers?* In addition to the lower success rate, the bottom 20% of businesses exhibit more than around 3.5 times the failure rate than the winning 20% according to Cooper et al. (2004). Furthermore, this also directly corresponds to the percentage of NPD projects, which are on time and budget (cf. Table 2). This emphasizes the importance of a successful and tough NPD process management.

For this reason, firms all over the world implemented *Stage-Gate®* processes as blueprints to overcome the *chaos* that comes along with the development of new products (Cooper, 1990). Thus, implementing a structured innovation process improves not merely structure of

Table 1 Percentage of businesses revenues and profits resulting from new products (NP) and percentage of businesses' new products failure, success and killed by type of business (source: In allusion to Cooper et al., 2004b).

Businesses	Revenues resulting from NP	Profits resulting from NP	Commercially successful projects	Commercially failing projects	Projects killed prior to launch
Top 20%	38.0	42.4	79.5	8.1	4.3
Bottom 20%	9.0	9.1	37.6	28.4	25.7
Average	27.5	28.4	60.2	20.8	19.0

Table 2 Percentage of businesses´ new products (NP) on time and budget (source: In allusion to Cooper et al., 2004b).

Businesses	NP projects launched on schedule in %	NP projects late in time as % of schedule	NP projects on budget in %
Top 20%	79.4	17.2	79.0
Bottom 20%	20.5	44.3	15.5
Average	51.1	35.4	57.1

the process but also increases the success rate of the NPD process (Cooper, 2008). In general, NPD processes combine a conceptual and an operational perspective to bring a new product from idea to launch (Cooper, 2008). Cooper (1990) states that managing NPD processes comprises the improvement of effectiveness and efficiency by integrating discipline into an ad-hoc and seriously deficient process (Grönlund et al., 2011). Based on this, Cooper (2001) emphasizes the importance of a well-structured NPD process by defining the world´s marketplaces as highly competitive *battlefields*. Cooper (2001) additionally highlights more recent combatants, which gained prominence due to fast and numerous new product victories, such as *Apple*, *Glaxo* and *Nortel* (Cooper, 2011; Cooper, 2008; Cooper, 2001). The weapons to win this *fight* are the thousands of new product launches, which should enable the firms to invade the chosen marketplaces. Although all *troops* are important to win this *fight*, the *battle* is often already won within the cradle of innovation, the R&D departments (Cooper, 2011; Cooper, 2008; Cooper, 2001). Cooper (2001) reduces the high failure rate in NPD process to the following circumstance:

"The combatants have their generals - the senior executives who plan and chart direction and attempt to define a business and technology strategy for their firm. The generals speak in terms of strategic thrusts, strategic arenas, and the need for strategic alignment. Sadly, many generals haven't really grasped the art of new product or technology strategy very well. So, as is often the case with ill-defined strategy, the battle is won or lost tactically in the trenches by the shock troops and infantry".

Since most of new product developments fail, the desire to generate *weapon* superiority by adapting the NPD process to the changing market environment rises (Cooper, 2001). Hence, firms recognized the necessity of adjusting their NPD process. Griffin (1997) has identified that 60% of all investigated NPD functions implemented a form of *Stage-Gate*® process to improve product innovation (Griffin, 1997). Today, the positive influence of *Stage-Gate*® processes on being successful at new product conception, development, and launch has been shown to a great extent (Cooper, 2019). The most crucial *weapons* are speed, strategy, and tactics in NPD processes due to decreasing product lifecycles and increasing competition (Cooper, 1990). Speed to market ensures competitive advantage by recognizing costumer´s demand faster than competition, it also yields higher profitability by realizing revenues earlier, and minimizes surprises by evading the threat of fast changing market environments (Cooper, 2001). Strategy focuses on the determination of the strategic direction of the NPD process, products, and technologies to invest in, while tactics describe a set of *maneuvers* designed to bring a new product from idea stage to launch (Cooper, 2001).

To put it in a nutshell, it seems that only some firms possess the knowledge on how to successfully adjust the NPD process on a regular basis with the goal to outperform their competition in the long-term. In contrast, many firms still fail with their NPD process. These failures have been empirically traced back to missing order, poor organization, inadequate quality of execution, and missed timelines (Cooper, 2008). Therefore, the firms need to set up NPD processes matching their market and competitive position (Cooper, 2008). An overview on the evolution of NPD processes over the last decades is displayed in Figure 1. Literature utilizes the terms system and model as synonyms for the term process. The different NPD processes will be presented in the subsequent chapters.

2.1 Introducing the *Stage-Gate®* process: the original *Stage-Gate®* process by Cooper

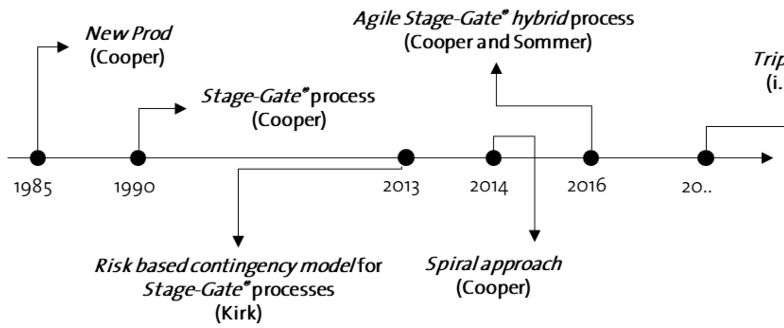
Cooper (1985) introduced *New Prod* to increase effectivity, efficiency, commercial success, and reduce development times (cf. Figure 1) (Cooper, 1985). The New Prod process was the first precursor of the *Stage-Gate®* model.

The original *Stage-Gate®* process was created by Cooper in the late 1980s based on in-depth studies of both, firms being successful with passing new products from idea stage to market, and firms failing at NPD (Cooper, 2014). The most rudimentary form of a *Stage-Gate®* process has been presented by Cooper in 2008. Within this simplest concept, a series of stages containing the collection of information, data integration, and analysis is followed by gates, where Go-/Kill-decisions adjudicate on the project's resource investment (cf. Figure 2).

Cooper (2008) compares the simplest form of a *Stage-Gate®* process with buying options on an investment, where initially inexpensive options were purchased and afterwards a decision regarding the investment´s perpetuation has to be made. Today's most commonly used representation of the original *Stage-Gate®* process is shown in Figure 3.

In general, the whole innovation process can be seen as a series of stages. Individually for

Figure 1 The evolution of NPD processes over the past decades (source: Own representation, 2020).



each stage a set of required or recommended best-practice activities are defined, which must be fulfilled that the product idea can pass to the next decision point (Cooper, 2008).

The original *Stage-Gate®* process starts with the ideation stage, namely *Discovery*, and culminates in the *Post-Launch review* (Cooper, 2014). The intermediate stages can be classified in homework phases to conduct required activities. While the initial stages do not require large financial expenditures, phases after *Go to Development* require serious financial commitments (Cooper, 2008). Following each stage, a Go-/Kill-decision (*Gate*) is made which decides on the project´s progress. Thereby, every gate has a similar structure comprising defined deliverables as visible results which are the output of the preceding gate´s discussion. These gates also contain criteria against which the project is judged. Thus, the criteria are subdivided into *should meet and must meet criteria* (Cooper, 2008). These categories of criteria are utilized to prioritize projects and to decide on its progress (Cooper, 2008). Moreover, the discussion at each gate results in outputs representing the go/kill-decision and a concrete action plan for the following stage, such as new deliverables (Cooper, 2008). Furthermore, the *Stage-Gate®* process consists of a series of stages which contain a set of required best practice activities leading to the process´s progress (Cooper, 2008). These activities contain market-oriented idea generation activities, such as focus groups and Voice of Customer (VoC) research in order to determine unmet customer needs (Cooper, 2019).

The activity and actions of each stage and gate of the original *Stage-Gate®* process from Cooper (1990) are summarized in Table 3.

Cooper (2008) describes this process as

Figure 2 Most rudimentary form of a *Stage-Gate®* process (source: In allusion to Cooper, 2008).

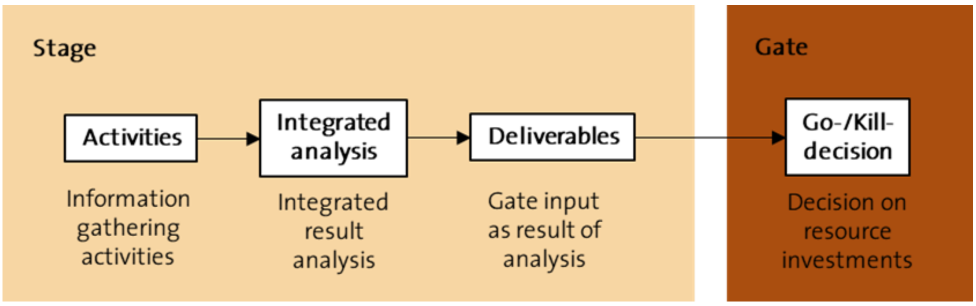
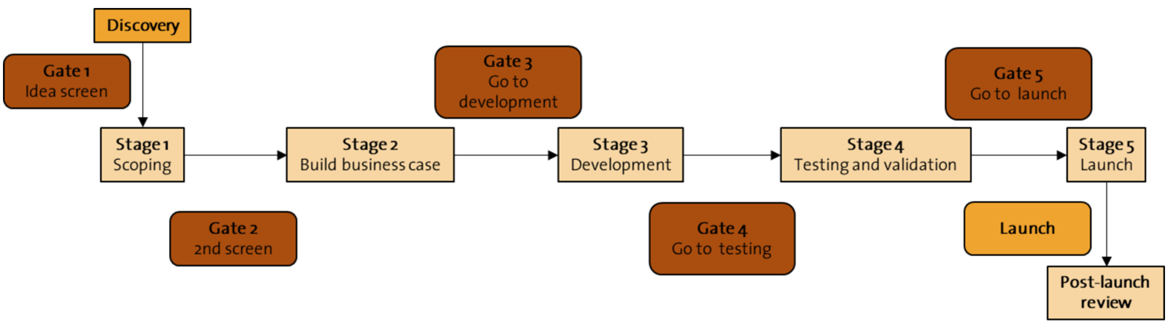


Figure 3 Standard *Stage-Gate®* model in NPD (source: In allusion to Cooper, 2014).



games of football including well-defined strategies, clear purposes, and proficient execution. Hence, the stages are designed to decrease risks and uncertainties by gathering required information, which may be adapted to the purpose of the different stages. Since the stages build on each other, each stage is costlier than the preceding one because of additional approved resources. However, the initial risk is managed by constantly decreasing uncertainties and unknowns.

2.2 Extending the *Stage-Gate®* processes

The *Stage-Gate®* process has been enhanced and adapted to changing corporate environments over the last 30 years. However, most firms maintain the basic concept from Cooper (Cooper, 2014). The advanced next generation processes should be more agile, flexible, dynamic, accelerated, and simultaneously leaner, faster, more adaptive, and risk-oriented (Cooper, 2014). Though, the criticism on sprawling bureaucracy and extended development periods was seized and implemented in the next generation of *Stage-Gate®* systems. The execution and implementation of these processes are quite different compared to the primary model from Cooper, although the framework of gates and stages remains the same (Cooper, 2014; Ettlie and Elsenbach, 2007). The new idea-to-launch processes comprise several novel aspects which are elucidated in detail below. The *Triple A system* represents the coalition of all these new approaches, which will be presented in chapter 2.2.5.

Table 3 Activity and underlying actions of each stage and gate within the original Stage-Gate® process (source: In allusion to Cooper, 2011, 2001, 1997, 1990).

Stage/Gate	Activity	Actions
Start	Discovery	Generation and collection of promising new product ideas.
Gate 1	Idea screen	Selection and prioritisation of product ideas for NPD project within a dynamic process with high uncertainty.
Stage 1	Scoping	Rough market and technology analysis such as assessment of basic financial values.
Gate 2	2nd screen	Decision on project´s progress based on profound conditioned information collection and analysis.
Stage 2	Build business case	Conceptualization of business case including detailed development and market launch plan.
Gate 3	Go to development	Decision on project´s profitability and release of exalted resources.
Stage 3	Development	Technological development and evaluation of marketing and fabrication activities.
Gate 4	Go to testing	Assessment of project's technical feasibility and control of R&D spending.
Stage 4	Testing and validation	Evaluation of customer acceptance, validation of financial planning and technological achievements.
Gate 5	Go to launch	Approval of market launch.
Stage 5	Launch	Market launch and product commercialization.
Post-launch review	Monitoring	Evaluation of launch process.

2.2.1 The spiral approach

An early, sharp, and fact-based product definition has always been one of the major requirements of the primary *Stage-Gate®* model (Cooper, 2011). In former times, the general tonus has always been that customers do not know what they want or need (Isaacson and Jobs, 2011). However, nowadays a fast-changing market environment as well as fluctuating customer requirements avoid a stable product definition in early stages of the NPD process (Isaacson and Jobs, 2011). Therefore, the primary product definition may be rendered invalid due to changing requirements during the process based on competitive developments or new market trends. Hence, the new *Stage-Gate®* processes must be orientated to fluid requirements and information, which on the other hand must be integrated into the process to decrease response time and increase efficiency (Cooper and Sommer, 2016). The integration can be achieved by the incorporation of spiral development cycles designed to directly integrate the customer´s feedback (Cooper, 2017a). Additionally, such an iterative process supports the appropriate product development and steers the development progress. This gains importance in rapidly changing markets, when some information is unsolidified and partially unreliable at the beginning of product development (Cooper, 2019). In pre-development stages, firms should avoid the usage of rigid and linear NPD processes comprising only the market assessment since a market might not exist yet. (Potential) customers should be rather involved (Cooper, 1988). As a consequence, the rigid process may culminate in the failure of new product launches due to today's fast-paced world. These failures can be avoided by stepping a cycle back in the NPD process to rethink the product's properties (Cooper, 2019). These iterative steps include the demonstration of preliminary versions of the product to the customer and the verification and integration of the customer´s feedback (Cooper, 2017a).

In general, each iteration stage consists of the following phases (Cooper, 2014):

1) **Build**: Start with building something what can be shown to the customer, this may be a rapid prototype, a protocept, a crude working model, or an early beta version.
2) **Test**: Test each version of the product with customers. Let them tell you what they like and what value they see.
3) **Feedback**: Gather feedback on the respective version of the product from the potential customer or user.
4) **Revise**: Reset your thinking about the value proposition, benefit and the product's design based on the feedback. Then, start again, and may go back to step 1) build.

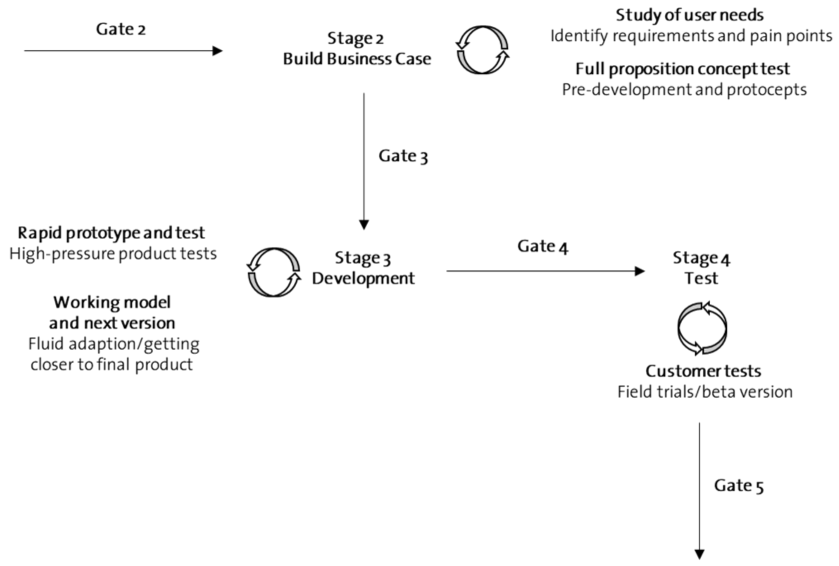
Each iteration enforces an adaption step that brings the product closer to its final design. Furthermore, this spiral development approach allows and encourages to fail often, fast, and cheaply (Cooper, 2014).

Figure 4 illustrates the spiral development phases as a novel aspect of the next generation *Stage-Gate®* processes. The spiral approach has no impact on stage 1 and 5, and thus both remain the same as in the original *Stage-Gate®* process. For this reason, they are not shown in Figure 4.

A regular alignment of the product´s design with the customer´s feedback does not merely decrease the market uncertainties but also strengthens the technical development. This is based on the customer´s high-pressure tests, in which the technical knowledge of customers is used.

Currently, statistical studies have rarely proven the advantages of the integration of spiral phases into the *Stage-Gate®* process. However, first evidence exists that this integration results in higher and better output, as 44.8% of best-performing firms practice these "build - test - feedback - and - revise" iterations, whereas only 26.3% of average-performing

Figure 4 Integration of spiral development phases in *Stage-Gate®* process. Note: Stage 1 and 5 remain the same as in the original *Stage-Gate®* process (source: In allusion to Cooper, 2014).



firms do (Cooper, 2012).

The spiral approach is congruent with the two core doctrines of the *Agile Manifesto* for software development - focus on quick response to change and continuous customer or stakeholder involvement in the development of the product – and thus, has a direct linkage to the subsequent aspect of next generation *Stage-Gate®* systems (Cooper, 2014).

2.2.2 *Agile-Stage-Gate®* processes

Agile development methods have been primarily created for software projects. However, within the last years agile methods have been also integrated into traditional stage-gating approaches resulting in an *Agile–Stage-Gate®* hybrid process in 2016 (Conforto and Amaral, 2016; Cooper and Sommer, 2016). The agile methodologies are based on the *Agile Manifesto* crafted by IT industry leaders in 2001 and incorporate a set of rules how to efficiently develop new software codes (Beck et al., 2001; Highsmith et al., 2001). The *Agile Manifesto* comprises the four following joint values (Beck et al., 2001):

- Individuals/Interactions more important than processes and tools
- Working software more important than comprehensive documentation
- Customer collaboration more important than contract negotiation
- Adaption instead of following a rigid plan

These four core values are antithetic to the initial purpose of the original *Stage-Gate®* process, since they omit a strict documentation and are geared to the customer instead of the process (Highsmith et al., 2001).

For the development of physical products, skepticism proliferates among industrial representatives and researchers whether the incorporation of agile methods into traditional NPD processes can be beneficial. Currently, only limited evidence in literature exists, which proves that the integration of agile methods into existing *Stage-Gate®* systems has beneficial effects (Conforto and Amaral, 2016; Cooper and

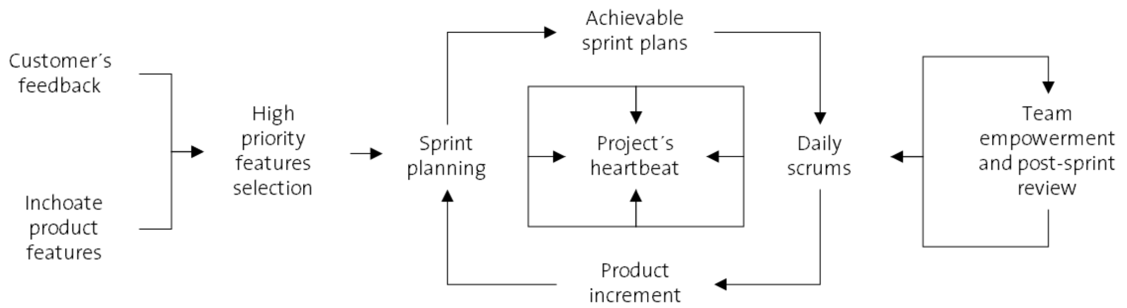
Sommer, 2016). However, after first trials and the implementation of hybrid processes in the manufacturing industry, positive effects have been shown by a few studies (Cooper, 2014; Cooper and Sommer, 2016; Sommer et al., 2014). These positive effects cover a wide field of benefits which are (Cooper, 2017a; Cooper and Sommer, 2016):

- Improved focus and prioritization
- Higher team morale
- Increased intersection between process and methods
- Improved productivity
- Improved communication and coordination
- Faster response to change

In addition, the benefits of *Agile–Stage-Gate®* hybrid processes contain the advanced focus on customer needs, the integration of the VoC, avoiding the problems of resource allocation, and the reduction of development cycle times (Conforto and Amaral, 2016; Cooper and Sommer, 2016).

The *Scrum* method of the *Agile Manifesto* represents the most popular version of the *Agile principle* and is mostly chosen for the integration into *Stage-Gate®* processes (Cooper and Sommer, 2016; Sommer et al., 2014). Therefore, the *Agile–Stage-Gate®* hybrid process incorporates the sprints of the *Scrum* method. These *sprints* are executed in very short time frames, characteristically one to four weeks. In doing so, the whole NPD process is separated into various small working packages. Each working package represents one *sprint*. *Sprints* in combination with a set of other activities form the framework and *heartbeat* of the agile project management according to Wells (2009) The framework is illustrated in Figure 5. For each iteration, customer´s feedback and an inchoate product is required to generate a valuable input for the process. The input and therefore the features must be prioritized before this information will be utilized within the agile process. Following the collection of valuable data and information, the agile development starts with the sprint planning to define realistic goals, which can be achieved within a given timeframe (Wells, 2009). Thus, *sprint planning* yields a *sprint-plan* containing all actions that are necessary for the accomplishment of the previously defined goals (Cooper, 2017a). Moreover, daily *Scrums* are executed, in which the team reviews what has been accomplished and which new problems and challenges occurred. In addition, a discussion takes place how these problems or new challenges can be solved (Abrahamsson et al., 2002). The preponderant goal of each *sprint section* is to deliver an improved prototype or protocepts that can be tested by the customers and other relevant

Figure 5 Process and framework of *Agile–Stage-Gate®* hybrid processes (source: In allusion to Wells, 2009).



stakeholders (Cooper, 2017a). Since the manufacturing industry requires longer development times than the software industry, the deadline for *sprints* can be more flexible. Additionally, the finished prototype must not be a physical product but can be a completed design drawing, a computer simulation, or even the reworking of the VoC results (Cooper, 2017a). Building on the feedback, the project team decides on the improvements that have to be completed within the next iteration step (Abrahamsson et al., 2002). Simultaneously, the incorporation of senior management via *post-sprint reviews* is crucial for these *Agile–Stage-Gate®* hybrid processes because physical product development is generally resource intensive and thus, senior management needs to approve necessary resources (Cooper, 2017a).

Agile–Stage-Gate® hybrid processes become particularly relevant in the development and testing stages of new physical products, since customer feedback shows the highest impact at these development phases (Conforto and Amaral, 2016; Cooper, 2017a). However, it should not be withheld that *Agile–Stage-Gate®* hybrid processes rather prove their most promising results at riskier projects (Cooper, 2017a). Indeed, customer integration bears the danger of know-how loss and may limit the development of disruptive innovations. The integration of short-sighted customer feedback could additionally rather result in the development of incremental innovations (Cooper, 2017a).

2.2.3 The risk-based contingency model for *Stage-Gate®* processes

The risk-based contingency model for *Stage-Gate®* processes based on the Corning´s approach was introduced in 2013 by Kirk (2013) and the most significant characteristic is custom-tailoring the process to every project uniquely (Cooper, 2014). This approach has the goal to generate detailed data and information that should support the decrease of uncertainties and increase the management of risks (Cooper, 2014, 2017b). It creates a hybrid system by integrating a business model canvas approach into the *Stage-Gate®* process and enables a custom-tailored process. Before applying the risk-based contingency model, these first three steps must be completed (Cooper, 2014; Kirk, 2013):

1) Identifying key uncertainties and unknowns
2) Highlighting critical economic assumptions
3) Determining the required data to validate these assumptions

By following this approach, the project team needs to define by themselves all deliverables which are required for the next gate. In doing so, a rigid and mandatory manual with a list of pre-defined deliverables and information required becomes invalid (Kirk, 2013). Thus, the generation of irrelevant information for the specific project can be avoided and results in the speed up of the NPD process (Cooper, 2014). Hence, this approach circumvents the evaluation of criteria which have no explicit value for the specific project (Cooper, 2014; Kirk, 2013).

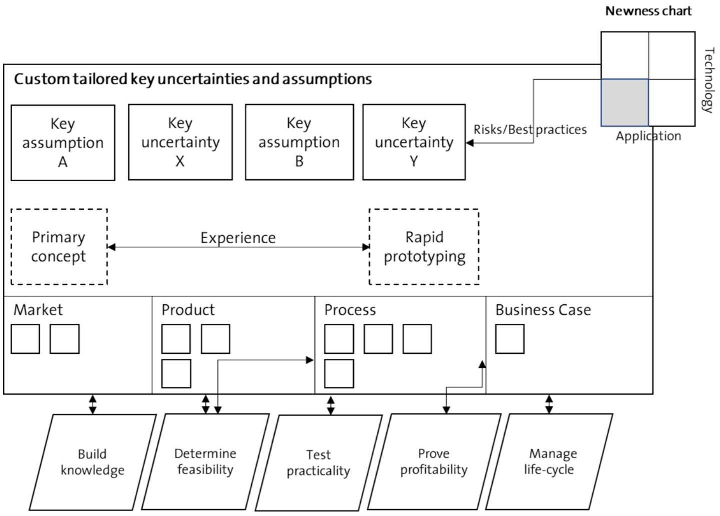
The assessment criteria are also flexible and can be adapted to the respective critical assumptions and uncertainties of the specific project. The set-up time of the project can be minimized by utilizing this process. In contrast, the original process requires the assessment and examination of all criteria (Cooper, 2014). Figure 6 shows Corning's risk-based contingency model.

2.2.4 Flexible *Stage-Gate®* processes

At the beginning of each project, the ideas collected must be categorized by their complexity, initiative risks, and precision of product definition to choose the most suitable NPD process.

Cooper and Edgett (2012) proved the importance of flexible NPD processes by identify-

Figure 6 Corning's risk-based contingency model (source: In allusion to Kirk, 2013).



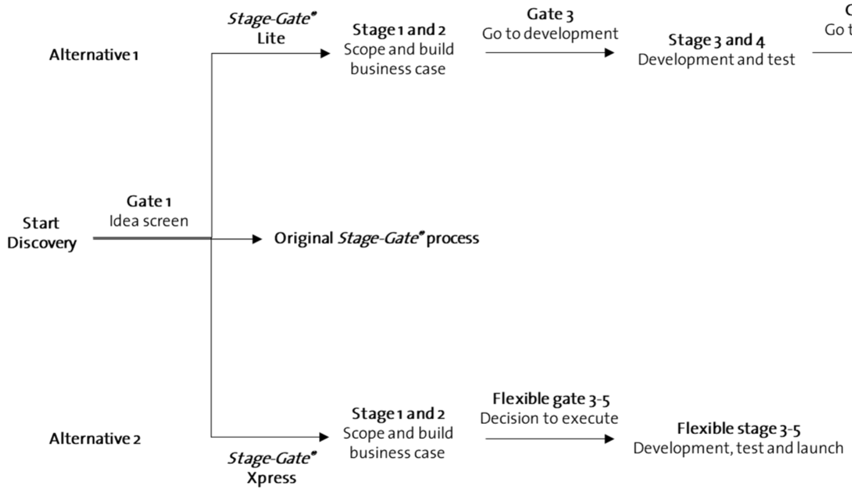
ing 75% of best-performing businesses using a scalable idea-to-launch process. In this context, flexible and scalable means that the execution time of the NPD process can be reduced or extended depending on each respective project. This gains in importance for accelerating the process while avoiding the waste of resources on disproportionate long development phases which are not necessary for every project (Cooper and Edgett, 2012).

The original *Stage-Gate*® process suits not to every project since many companies execute projects with different degrees of complexity. Therefore, flexible context-based *Stage-Gate*® processes comprising *Stage-Gate*® *Lite* and *Stage-Gate*® *Xpress* have been created to adapt and accelerate the NPD process. These context-based approaches allow skipping gates and stages to cope with different degrees of complexity (Cooper, 2014). In this context, synchronization of activities plays a crucial role in terms of accelerating and adapting the process (Cooper, 2014).

Whereas the full six-stage process of the standard *Stage-Gate*® process is suitable for major high-risk development projects, the lite version (*Stage-Gate*® *Lite*) has been created to handle projects with moderate risks, e.g. in terms of product modifications and improvements (Cooper, 2014; Leithold et al. 2015). Moreover, the express process (*Stage-Gate*® *Xpress*) can be utilized for small development projects, e.g. customer-based adaptions of single products (Cooper, 2014; Leithold et al., 2015). Figure 7 shows the *Stage-Gate*® *Lite* and *Stage-Gate*® *Xpress*.

For the acceleration of the NPD process, time wasters and blockages must be identified through value stream analysis and removed to increase efficiency of the process. Therefore, the most prominent options to fulfil these goals comprise 1) overlapping stages, 2) simultaneously executed activities, 3) dedicated teams assigned with adequate resources, 4) efforts to sharpen the fuzzy front end in terms of properly understanding the customer´s problem, and 5) defined support systems for the project management (Cooper, 2014; Leithold et al., 2015). The simultaneous execution of several tasks, including key-activities and overlapping stages, requires the permission to move ahead even though information are not fully available and validated (Cooper, 2014). Thus, the support and commitment of top management can enforce speed and flexibility of the NPD process. In doing so, multiple activities can be carried out in

Figure 7 Flexible and scalable *Stage-Gate®* processes as alternatives for the original *Stage-Gate®* process including *Stage-Gate® Lite* and *Stage-Gate® Xpress* (source: In allusion to Cooper, 2014).



parallel. This is much more suitable for development projects with several parallel tasks than a *relay race*, at which activities are successively executed (Cooper, 2014; Leithold et al., 2015). This kind of acceleration and flexibility also allows to move activities to an earlier stage than scheduled and to start with a following stage when the previous may not be completed yet. In particular, the necessity of these accelerated and adapted NPD processes increases due to increasingly shortened product life cycles in manufacturing industries such as the chemical industry (CHEMonitor, 2014; Roland Berger, 2014; Daubenfeld et al., 2014).

2.2.5 Combining novel *Stage-Gate®* processes: The *Triple A system*

Cooper (2014) combined the previous presented approaches in the *Triple A system*, which represents the next generation of idea-to-launch systems. The three main goals of the Triple A system are adaptivity (flexibility), agility, and acceleration to improve the original *Stage-Gate®* process. However, the framework how to manage NPD projects still remains the same, although the details of the process and its purpose are quite different. The *Triple A system* will probably be the underlying concept of all next generation stage-gating systems.

1) **Adaptivity/flexibility**: The integration of a **spiral development** approach ensures the fast design and production of prototypes while utilizing and integrating customer's feedback (Cooper, 2014). At the beginning, the product design and its value proposition may not be fully defined but becomes more concrete during the iterative process. Therefore, the product may be adapted based on the respective customer requirements. For each development process, flexibility can be ensured by uniquely defining and selecting the actions and deliverables required for each stage and gate (Cooper, 2014). For lower-risk projects, fast-track versions of the original *Stage-Gate®* process can be used to speed up the NPD process. The respective decision, which version is used, is based on an assessment of each project´s risks and opportunities. Finally, single activities can be flexibly assigned to several gates. Assessment criteria of each gate are also flexible

and not rigid.

2) **Agility**: The *Triple A system* integrates elements of the **agile development method**, like *sprints*, *Scrums*, and the necessity of involving all stakeholders into the NPD process, especially customers (Conforto and Amaral, 2016). The NPD process should culminate in moving nimbly from idea to market launch by utilizing the knowledge from agile software development. It also relies on a much leaner system which avoids bureaucracy and unnecessary activities during the development phase (Cooper, 2014; Karlström and Runeson, 2006).

3) **Acceleration/speed**: The *Triple A system* f ocuses on methods, which ensure the accel eration of the NPD process. Therefore, fluid s tages containing overlapping activities cul minate in an accelerated process and an early identification and evaluation of risks and uncertainties. It should not be withheld that flexible and accelerated processes re quire decision making even with less infor mation availability what could result in a higher failure rate. Thus, especially decision-makers like top management play a crucial role to accelerate and speed up the NPD pro cess. They must approve resources for the continuance of an NPD project, although not all necessary information may be availa ble.

Regarding the improvement or modification of the *Stage-Gate®* process, **Adaptivity**, **Agility**, and **Acceleration** should be kept in mind as core elements whenever conducting an NPD process or implementing a new *Stage-Gate®* process into an organisation. In the next chapter, an example of how a chemical company can adapt its *Stage-Gate®* process for NPD will be presented.

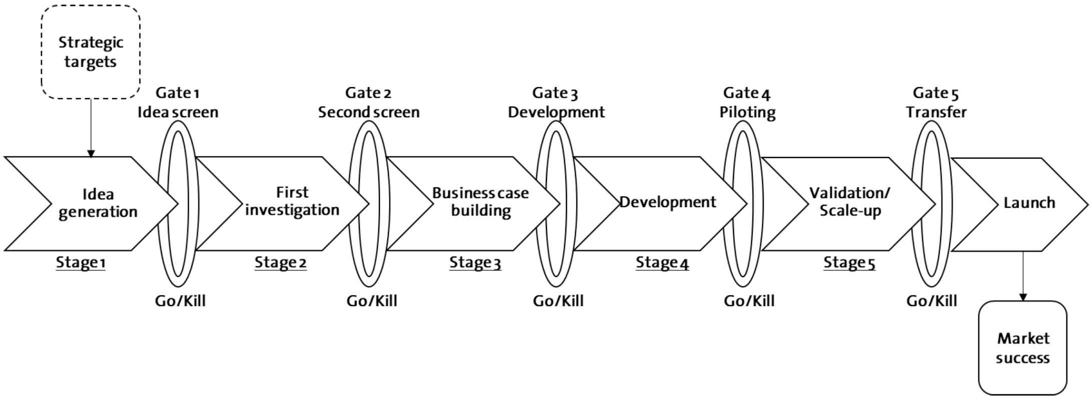
3 Customizing the *Stage-Gate®* process: an example from the chemical industry – The *I2P3®* process

Evonik Creavis GmbH introduced the *I2P3®* process, which is adapted to the chemical industry by including an evaluation of the whole industrial environment (Wojciechowski et al., 2019). In addition, the *I2P3®* process takes all three dimensions of the triple bottom line into account: People (societal aspects), Planet (ecological aspects), and Profit (economic aspects) (Wojciechowski et al., 2019). Figure 8 shows the whole *I2P3®* process, which comprises six stages like Cooper´s original *Stage-Gate®* process. Within the *I2P3®* process, substantiated decisions are based on a set of categories and criteria focusing on all three dimensions of the triple bottom line concerning sustainability, which are specifically assessed and examined during the gate decisions (Wojciechowski et al., 2019). These three categories have been selected since they are considered to be particularly relevant for the chemical industry. Besides, further sub-criteria have been defined to specify each category (Wojciechowski et al., 2019). For instance, global warming potential based on a 100-year timeframe is a criterion within the category of reduction of Greenhouse gases emissions (Wojciechowski et al., 2019).

The *I2P3®* process contains two kinds of criteria, qualitative and quantitative. While quantitative criteria are described by continuous values, qualitative criteria provide multichotomous scores based on a benchmark. This ensures a comparative assessment and allows qualitative values to be semi-quantified (Wojciechowski et al., 2019). Quality and validity of the information of each criterion is increased with the project´s progress (Wojciechowski et al., 2019).

Since new innovative ideas are uncharted when entering stage 1, the quantitative assessment of criteria because of data quality is challenging and not well-founded at the fuzzy front

Figure 8: Structure of the I2P3® process (source: In allusion to Wojciechowski et al., 2019).



end. Therefore, rather qualitative criteria are used at the beginning of the process. However, the continuous assessment of the People, Planet, and Profit dimensions ensures an increasing data basis in addition to rising data quality during the process (Wojciechowski et al., 2019).

At the beginning of the *I2P3®* process, a product or process improvement or novel idea is generated, which is filed into the *I2P3®* process by the idea generator and subsequently discussed during a first gatekeeper meeting (Wojciechowski et al., 2019). Within this first assessment, primary estimations of the market and technical feasibility are required and assessed by a Life-Cycle-Management (LCM) expert to create insights into how the product could affect the sustainability criteria (Wojciechowski et al., 2019). In case of a positive verdict, the idea generator is allowed to continue and collect all data, which are mandatory for the gate 2 assessment (Wojciechowski et al., 2019).

In congruence with the original *Stage-Gate®* process from Cooper, gate 2 assessment contains a more detailed evaluation resulting in a more refined appraisal of all relevant criteria since it comprises more detailed information on the exact product development (Wojciechowski et al., 2019). However, the accountable project manager will present the most likely scenarios based on semi-quantitative information (Wojciechowski et al., 2019). This approach ensures the evaluation of positive and negative characteristics of the idea. Further resources will be released, if the idea was positively assessed to pass gate 2 and to advance to stage 3 (Wojciechowski et al., 2019).

The assessment of gate 3, 4 and 5 is similar since the respective criteria contain the same data and factors used in gate 1 and 2, but vary with their accuracy (Wojciechowski et al., 2019). Thus, the *I2P3®* process is not a rigid but flexible process, which can be adjusted when necessary depending on the respective project and situation (Wojciechowski et al., 2019).

Within the validation and scale up stage (stage 5), the entire project´s viability and estimated impact on the sustainability criteria is scrutinised (Wojciechowski et al., 2019). After a successful assessment of all gate 5 criteria, the newly developed product or process reaches the launch stage (Wojciechowski et al., 2019). In doing so, the *I2P3®* process comprises the economic, ecological and social impact of the project, which are necessary to successfully introduce the product into the market and to comply with regulation. The *I2P3®* process can be easily adapted to a changing market environment and new qualitative scoring approaches can be integrated (Wojciechowski et al., 2019). Indeed, the high flexibility of the process requires a good understanding of the market and sustainability requirements of the customers (Wojciechowski et al., 2019).

With the introduction and implementation of the *I2P3®* process, Evonik Creavis GmbH has responded to changing market environments of the chemical industry, in which customers increasingly ask for sustainable products. As a consequence, it individually adapted the standard *Stage-Gate®* process to meet changing customer requirements, but also to accelerate the NPD process (Wojciechowski et al., 2019).

4 Conclusion

Until now, the basic framework of the original *Stage-Gate®* process by Cooper is still used as a guideline how NPD processes can be structured. However, single activities and deliverables may be adapted to specific industries and projects to manage NPD processes effectively and efficiently.

For both physical and non-physical product developments, advanced *Stage-Gate®* processes were presented in this paper, which are suitable to bring new products and services quickly, efficiently, and profitably to market. Best-practice firms serve as a role-model for how to design and implement advanced NPD processes to deal with changing market and customer requirements. *The Triple A System* allows adaptivity (flexibility), agility and acceleration (speed) of NPD processes. In addition to the presentation of these flexible, adaptive, and scalable *Stage-Gate®* processes, the main purpose of this review is to convey the need of custom-tailoring the NPD process. Therefore, every firm should be admonished to adapt their NPD process or to use different types of NPD processes according to its industrial landscape and to every single project. This can help firms to develop NPD capabilities to outperform their competitors in the long-term. Finally, chemical companies may especially use agile methods to develop new (digital) services and business models around their physical products.

5 Outlook for future research

Over the last decade, much qualitative research in terms of working hypotheses and model development has been published regarding the improvement and flexibilization of NPD processes, whereas these new approaches find no broad application in any industrial sector so far. Therefore, it is the researchers´ task to evaluate the benefits by conducting empirical analyses and thus, creating the basis that enforces firms of different industrial sectors to have confidence in these new approaches. This confidence will then help firms adapting and redesigning their NPD processes.

Furthermore, success factor analyses and how their relevance change during the NPD process should be conducted to provide a well-founded playbook how these new approaches can successfully be implemented and managed in practice. For this reason, success factors for every industry and every single phase of the NPD process must be identified at a first level. This will help to obtain insights into the crucial factors yielding success. This knowledge will help firms to custom-tailor their respective NPD process by providing information on the suitability of NPD processes for certain industries and single projects to improve successful NPD and to help firms to outperform competitors in the long-term.

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