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Chapter 4

An Integrative Model for Technology-Driven Innovation and External Technology Commercialization

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ABSTRACT

This chapter proposes an integrative model for internal and external commercialization of technology-driven innovation. It particularly addresses how firms can practically use external technology commercialization, which is a type of open innovation that is not yet fully understood by academics and managers alike. The chapter first reviews dominant literature and frameworks in the areas of innovation, technology-driven innovation, and external technology commercialization. It subsequently develops an integrative model of technology-driven innovation and external technology commercialization, which combines various extant frameworks of internal and external commercialization of internal technologies and thereby provides a holistic understanding of what it takes to successfully commercialize technology. The model presents various phases in the process from technology to commercialization, such as divergence, convergence, technology transfer, development, validation, commercialization, and product line expansion, and presents the relevant intersections and the alternative commercialization paths. Hereby, this chapter provides a holistic perspective and a practical tool for managers seeking viable commercialization opportunities inside or outside of their firm boundaries.

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INTRODUCTION

Research and practice in the area of open innovation has grown tremendously over the last few years, although a better understanding of the theory and practice of open innovation is still called for (Gassmann, 2006; Gassmann et al., 2010; West et al., 2006). Most research in open innovation follows Chesbrough (2003) who describes open innovation as the use of external sources of innovation and the associated opening up of firm boundaries. On the one hand, open innovation entails utilizing external innovation and knowledge to accelerate internal innovation (e.g. Laursen & Salter, 2006), while it, on the other hand, entails finding external commercialization paths for internal technologies (e.g. Lichtenthaler, 2009). This outbound perspective is based on the assumption that companies cannot or do not always want to internally commercialize their inventions but rather look for external applications to capture value from these inventions. However, as put by Enkel, et al. (2009) “while most researchers focus on the outside-in process, theory lacks of a clear understanding of the inside-out or outbound activities.” (p. 313) Accordingly, despite some case-based research and some recent studies that show prevalence of external technology commercialization (ETC) (Lichtenthaler & Ernst, 2007; van de Vrande, et al., 2009), a comprehensive and practical model that describes the process of ETC is yet to be developed. Moreover, to the extent that the literature addresses this issue, it is largely remote from also considering the alternative of internal technology commercialization. To further advance this area, this chapter proposes a model that provides an overview of the different

steps in the process of identifying commercially attractive applications when companies have a technology “on the shelf”, which also combines internal and external alternatives for technology commercialization. To reach this goal, the model provides a technology-driven view of the product development process, which integrates various frameworks in extant literature to provide a holistic perspective and a practical tool for managers seeking viable commercialization opportunities inside or outside of their own firm boundaries.

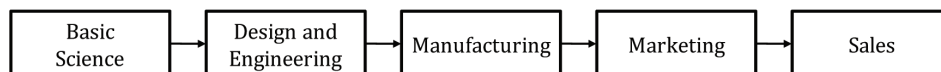
MODELS OF INNOVATION

While some innovation projects are driven by latent, unsatisfied customer needs (market-driven innovation), others are driven by the creation of a new technology or scientific breakthrough (technology-driven innovation). These two models have very distinct implications for how companies can and should manage the innovation process, not only in terms of creating new technologies but for finding viable commercialization opportunities as well.

One of the first known innovation models is Rothwell’s (1994) Linear Technology Push Model (Figure 1). Developed in the 1950s during a period of rapid industrial expansion, this model suggests that all innovation stems from scientific breakthroughs.

In the early 1970s, many markets were reaching maturity and overall competition among companies increased. In order to capture market share in mature markets, organizations were spending more resources on marketing. It became important to meet the client’s demands better than

Figure 1. Linear technology push model (adapted from Rothwell [1994])



the competition and this could be realized by analyzing customer requirements. New products were still being developed, but these were more often based on existing technologies. Market demand rather than technological breakthroughs started to dominate product development (Figure 2).

This paradigm shift gave rise to the linear market pull model. According to this model, innovation is based on market demands rather than on technological change.

It soon became clear however that both technological breakthroughs and market demand are crucial elements that drive innovation. Too strong a focus on technology brings the danger of losing market share, because competitors are more market focused. Working solely from the market pull model brings the risk of neglecting long term technology development, thereby losing the capability to react to discontinuous market or technology changes (Rothwell, 1994).

The realization that both technology push and market pull influence innovation gave rise to a number of models that recognize the importance of both inputs. An example is Rothwell's (1994) interactive model of innovation. It illustrates how innovation is initiated through an interaction between market demands, scientific and technological breakthroughs, and an organization's capabilities.

However, these models still focus on the firm's internal capabilities and do not take developments beyond the firm's boundaries into account. With the emergence of open innovation, a new paradigm shift occurred. Chesbrough (2003) explains open innovation as a paradigm in which firms can use both internal and external sources of innovation,

and internal and external commercialization paths as a way to expand the firm's options as it looks to advance its technology.

This chapter focuses on the outbound perspective of open innovation, that is, how companies can find external paths for commercializing internally developed technology (Enkel et al., 2009; Bogers & West, 2010). However, since the paths towards internal and external commercialization are closely linked and not mutually exclusive, a complete understanding of the various possible commercialization paths requires taking into account both internal and external paths towards technology commercialization.

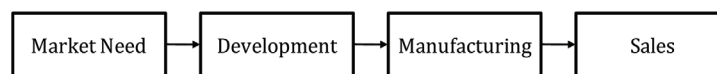
COMMERCIALIZING TECHNOLOGY-DRIVEN INNOVATION

Technology-Driven Innovation

After having reviewed the evolution of the industrial approaches to innovation (from technology-driven, to market-driven, to an integrated approach, and to open innovation), the chapter now specifically explores the role of technology-driven innovation (TDI) in the current practice of innovation, with a particular emphasis on ETC. Given that companies pursuing TDI projects face unique challenges when attempting to commercialize technological breakthroughs.

This chapter follows Herstatt and Lettl's (2004) approach towards TDI, to be used within the context of outbound open innovation:

Figure 2. Linear market pull model (adapted from Rothwell [1994])



A new technology, scientific breakthrough, or a new combination of technologies is the driving force behind the creation of new products.

This contrasts the market-driven innovation (MDI) approach, which is described as:

Latent, unsatisfied customer needs in the market place are the driving force behind the creation of new products.

Lettl (2004) argues that, while this simple description identifies how TDI projects differ from MDI projects in relation to their origin, there are at least five more identifiable differences, namely technological uncertainty, market uncertainty, R&D investment, development time, and the degree of innovation. This section of the chapter analyzes these unique characteristics of TDI projects and discusses how TDI differs from MDI.

TDI projects are subject to a high level of technological uncertainty. Since the technology is still in the development phase its exact capabilities and uses are often unknown. Potential market applications are also unknown and need to be formulated. There is no prior or exterior research base on which technological feasibility of market application concepts can be based. The process of transferring technology into real world applications is filled with uncertainty since the technology is not fully developed or mature. Lyn and Heinz (1992) identify the following reasons why the transfer from technology to market applications is seen as a difficult process within many technology developing companies:

- The new technology does not seem to solve specific or known market needs.
- The new technology is not a clear replacement for an existing technology.
- Companies tend to look for applications that make optimal use of the new technology. These however are not necessarily applications with the best market fit.

- Companies tend to focus their technology transfer towards the biggest market opportunity. Frequently, however, niche markets are better suited for the introduction of a new technology.

In MDI projects market needs are the input on which the development of new market applications can be based. Market applications can be developed with the use of existing and new technologies to fit a recognized market need. For TDI projects however market needs and potential applications are often unknown or extremely broad in scope. A direct result of this is that no concrete market information can be collected (Herstatt & Lettl, 2004). Basic information about such things as market size, customer needs, potential strategic partners, competition and suppliers remains unknown. Furthermore, once potential market applications for the TDI project have been identified, this does not put an end to the increased level of market uncertainty. This is due to the fact that TDI projects will either enter completely new markets, or enter an existing market with a technology that is not yet known to the existing customers. In the case of a completely new market for the firm there is a high uncertainty as to who the customer will be and how the application can best be developed and commercialized for this market. Traditional market research methods do not work for unexplored markets and companies must resort to more explorative methods, which provide less concrete results (Lyn & Heintz, 1992).

In the case of a TDI project in which an application is being developed to take over the existing market of applications based on older technology, a problem exists concerning customer learning (Herstatt and Lettl, 2004). Customers are not yet familiar with the new technology and will not be able to accurately voice their needs. Especially where consumer learning and a behavioral change are required, existing customers often form a negative opinion about the new application. In these cases, misinterpreted market information

can lead to the termination of extremely promising TDI projects. Figure 3 shows the market-related characteristics of TDI projects as opposed MDI projects.

The nature of TDI projects (commercialization based on scientific breakthroughs and new technologies) implies that in general the degree of innovation, the development time and scope, and the required R&D investments are significantly higher than in MDI projects. TDI projects aim at breakthrough or discontinuous innovation and for these types of projects the development time can extent over ten years.

Necessity of Technology-Driven Innovation

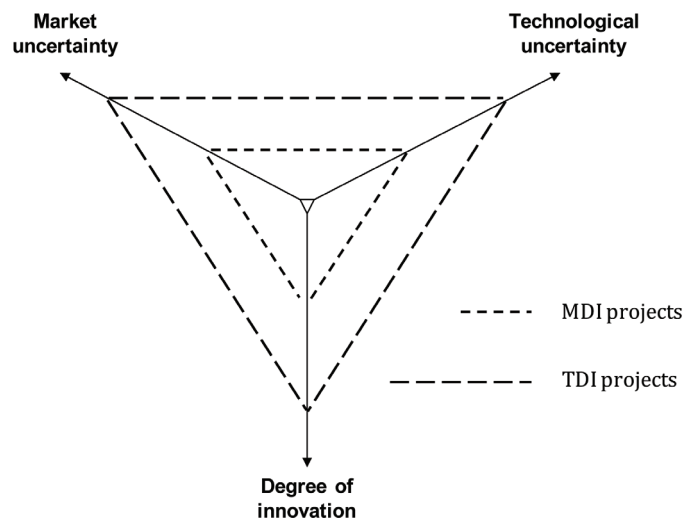
MDI projects are a crucial activity for all firms that want to stay competitive in their existing markets. Optimization of products is important and it allows companies to remain competitive during the entire product life cycle. Additionally, MDI allows companies to recognize unexplored market needs and use existing technologies to exploit these. It is important to remember that although

many discontinuous new products are based on new technology (Veryzer, 1998; McDermott and O'Connor, 2001), this is not a prerequisite, as will be explained later on in this chapter. Samli and Weber (2000) highlight the attractiveness of MDI as the input for product innovation:

“This orientation is less risky, less costly, and it generates quick results on the short run” (Samli & Weber, 2000 p. 36)

However, research shows that TDI projects are crucial to any technology-based firm’s long-term competitiveness (Hamel & Prahalad, 1991; McDermott & O’Connor, 2001; Samli & Weber, 2000). Technology-based firms that are not able to develop new technologies and use these to enter uncontested market space will eventually find themselves stuck in traditional, shrinking markets that are subject to intense competition (Kim & Mauborgne, 2005). Consistent investment into technology development and a company’s core competencies are prerequisites for creating new market space (Hamel & Prahalad, 1990). Development of new technologies provides the basis

Figure 3. Market-related characteristics of technology induced development projects (adapted from Herstatt and Lettl [2004])



on which a company's future product portfolio is built (McDermott & O'Connor, 2001). Thus, TDI projects are necessary for technology-based firms to achieve or sustain long-term competitiveness.

While uncertainty and risk are higher for technology driven new product development (NPD) projects, the profit potential is also greater (Samli & Weeber, 2000; Song & Montoya-Weiss, 1998). Successful TDI projects often form a new basis (or even core technology) on which a whole generation of new products can be built. The thesis that TDI projects have a higher profit potential than MDI projects is further supported by the research of Power (1993) who showed that for the period of 1989 to 1993 in his test group, new products based on breakthrough technologies accounted for 24 percent of the acquired profits, while this group represented only 10 percent of the new products brought into the market. Thus, TDI projects, although higher in risk, show a larger profit potential than MDI projects.

New technology that does not directly lead to new applications does not necessarily constitute a failed project. Hamel and Prahalad (1991) explain that these technologies can be reserved for future use. New applications are often created through a combination of existing technologies and they argue that companies with a broad base of existing technologies are more likely to find applications for uncontested market space. Accordingly, a broad technology base will increase a firm's capability to meet future market demands.

A final clear benefit of TDI projects is advocated by Elton et al. (2002). They show that large technology-based companies can earn up to 10 percent of their operating income from the sale and out-licensing of patents and proprietary processes. In line with the outbound open innovation perspective (Chesbrough, 2003; Lichtenthaler, 2005), this means that TDI projects that do not lead to any products within the firm's business areas can still prove to be (very) profitable through commercialization outside of the firm's boundaries. Therefore,

within the context of ETC, TDI projects have the potential to increase a firm's intellectual property, which can in turn be licensed-out or sold to firms operating in non-competing business segments.

Continuous vs. Discontinuous Innovation

Within TDI, distinctions can be made between different types of product innovation. This section addresses the difference between incremental or continuous and discontinuous product innovation.

Not all TDI projects necessarily lead to radical new product innovations, just as MDI projects do not only produce product line extensions. This part of the chapter analyzes the main schools of thought on continuous versus discontinuous innovation. The academic community does not agree on one clear definition of discontinuous product innovation. There are many descriptions and models to explain the difference between product line extensions, new to the world products, and everything in between. One of the dominating models and the one that is shown below is an adaptation of Veryzer's (1998) model, which focuses on the technological and market capabilities of new products (Figure 4). This chapter uses an adaptation of Veryzer's model to discuss the different classifications of continuous and discontinuous product innovation.

The model above uses two dimensions to classify the level of a new products innovativeness rating from continuous to technologically and commercially discontinuous. **Market capability** refers to the product benefits experienced by the new products customers and/or users. **Technological capability** refers to the level in which a technological change or improvement takes the new product beyond the technological boundaries of existing products (Veryzer, 1998). This model recognizes four general groups to categorize new product innovations, namely:

Figure 4. Types of product innovation (adapted from Veryzer [1998])

Technological capability	Advanced	Technologically discontinuous	Technologically and commercially discontinuous
	Same	Continuous	Commercially discontinuous
		Same	Enhanced
		Market capability	

Continuous. Continuous new products are products that are only marginally different from existing products. The new product uses conventional technologies and doesn't radically improve the customers and/or users product experience. Examples are line extensions in car production and Microsoft Office 2003 in software development.

Commercially discontinuous. Commercially discontinuous new products are perceived by the customer and/or user as really new even though they are based on existing technologies. Commercially discontinuous new products either drastically improve product experience in an existing market, or enter uncontested market space. Nintendo's Wii is a modern example of a commercially discontinuous product, offering new product benefits, while using existing technologies.

Technologically discontinuous. New products are technologically discontinuous when the product is technologically drastically different, and yet not perceived as different by the customer and/or user. The use of computer technology in car engines is one example; while the control of modern car engines has moved from the traditional mechanical system towards computer control, the consumer's perception of the car has not drastically changed.

Commercially and technologically discontinuous. These are the most discontinuous new products. Commercially and technologically discontinuous products use new technology to drastically improve perceived product benefits for the customer and/or user. An example is plasma technology, which makes it possible to produce huge flat screen televisions.

The focus of this chapter is on the latter two categories since ETC is the result of TDI projects. Technologically discontinuous products are developed with the intention of creating breakthrough products, which can enter uncontested market space or change the basis of competition in existing industries. Luecke (2006) argues that breakthrough new products can be recognized by the possession of one or more of the following three characteristics:

- The product offers an entirely new set of performance features.
- The product performance is many times better than that of alternatives currently in the market.
- The product can be produced at a sizable reduction of the cost, while offering the same or better features than products currently in the market.

Luecke (2006) summarizes the difference between incremental and breakthrough products as described in Table 1.

INTERNAL VS. EXTERNAL TECHNOLOGY COMMERCIALIZATION

New technology and intellectual property rights (IPRs) that result from TDI projects can be commercialized both within and outside of the firm’s boundaries. Both of these commercialization options have distinct characteristics with direct consequences on the process of commercialization. The unique challenges faced when commercializing on a new technology within firm boundaries will be discussed first before analyzing the firm’s possibilities for ETC.

Commercialization within the Boundaries of the Firm

In the previous sections of this chapter it became clear that MDI and TDI projects are different because they start with a different input (technology or market) and are generally aimed at a different type of output (incremental or breakthrough product innovations). Since TDI projects are often not initiated because of a recognized and clearly defined market need, and the market is not

familiar with the technology being introduced, the type of commercialization activities carried out for TDI projects should differ from those carried out for MDI projects. Table 2 summarizes how marketing tasks for commercialization within firm boundaries differ for TDI projects in comparison to MDI projects.

Conventional market research methods focus on existing markets and customer needs. Since TDI projects are based on new technology and often aimed at new markets, the conventional research methods are likely to provide misleading information. Song and Montoya-Weiss (1998) therefore argue that marketing activities for TDI projects should focus on strategic planning, rather than on the business and market opportunity analysis. One method used to overcome the limitations that are associated with traditional market research is to envision future markets rather than to research existing markets. Envisioning a market goes beyond estimating market size and projecting potential profits. Instead, there is a clear focus on the technology and business strategy. Following Urban et al. (1996), the process of envisioning the market includes forecasting the following elements:

- The evolution of the new technology.
- The development of new and adjacent applications.

Table 1. Incremental vs breakthrough new products (adapted from Luecke [2006])

Incremental	Breakthrough
<ul style="list-style-type: none"> • Improvement of an existing product • Extension of an existing product platform 	<ul style="list-style-type: none"> • New to the world • Huge advance in performance
<ul style="list-style-type: none"> • Lower risk 	<ul style="list-style-type: none"> • Higher risk
<ul style="list-style-type: none"> • More frequent 	<ul style="list-style-type: none"> • Less frequent
<ul style="list-style-type: none"> • Less costly to develop 	<ul style="list-style-type: none"> • More costly to develop
<ul style="list-style-type: none"> • Targeted to existing markets 	<ul style="list-style-type: none"> • Targeted to new or existing markets

Table 2. Key marketing tasks for MDI and TDI projects (adapted from Luecke [2006])

Key Marketing Tasks	
Market-Driven Innovation Projects	Technology-Driven Innovation Projects
<ul style="list-style-type: none"> • Listen to the existing market • Accommodate current demand 	<ul style="list-style-type: none"> • Envision the market • Create demand • Educate the market

- Decreasing cost price from initially high levels.
- The growth and maturing of the value chain.
- The entry of competition.
- Since the market is unfamiliar with the potential benefits associated with the technology being pushed to the market, firms need to make the market aware of the new technology in order to create a demand for the new products that they are offering. O'Connor's (1998) qualitative research into radical innovation projects pinpointed four strategies to generate market demand used by the companies in her research, namely to:
 - Offer the product to current customers.
 - Start a strategic alliance with a company that can introduce the new technology to the market.
 - Let the markets find the product.
 - Probe and learn.

When marketing technologically discontinuous new products to customers who are unfamiliar with them, it is crucial to educate the customer about the use and the benefits of the new product as compared to the existing standard. An often-used method is providing customers with product information prior to the launch of the product. This marketing technique (often called pre-announcing) prepares potential customers for the eventual launch of the product. Customers can delay new purchases since they have been informed of the radically new product being launched at a later date. By structurally informing potential customers about the upcoming product, its benefits, and how it can be used, pre-announcing can both educate and grow the market. Pre-announcing is however only one of the techniques that can be used to educate the market. Other examples include seminars and technology fairs. The main focus of educating the market is using PR activities to convey the benefits of the new technology, the new possibilities, and the company's vision

for the future to potential new customers (Beard & Easingwood, 1996). Incorporating opinion leaders and experienced users into the product development process can further help in market education and the creation of market awareness.

Commercializing New Technologies and IPR Outside of the Firm Boundaries

Another well-known but less researched path to the commercialization of internally developed technological innovations is ETC (Enkel et al., 2009). Nevertheless, recent empirical studies have shown that ETC, as a means of exploiting internal technology, is an increasingly important phenomenon (Lichtenthaler & Ernst, 2007; van de Vrande et al., 2009).

Bogers and West (2010) argue that a firm can choose to externally commercialize technology when the technology does not fit the firm's organizational capabilities or business model. Lichtenthaler and Ernst (2007) add to this that firms can furthermore choose to successfully apply internally developed technologies and IPR in their own organization while looking to externally commercialize within non-competing industries. Elton et al. (2002) estimate that for large firms (with at least 450 patents) ETC could account for 5 to 10 percent of the firm's operating income.

Lichtenthaler and Ernst (2007) identify the following functions of ETC, in order of importance:

- Guaranteeing freedom to operate
- Gaining access to external knowledge
- Realizing foreign market entry
- Guaranteeing technological leadership
- Selling additional products and/or services
- Setting industry standards
- Generating licensing revenues
- Enhancing the firm's reputation
- Strengthening the firm's networks
- Realizing learning effects
- Fulfilling legal conditions

This section of the chapter analyzes the different possibilities available to the firm for achieving ETC and what are some of the essential managerial considerations for successful ETC.

Here we follow Granstrand and Sjölander's (1990) typology of technology exploitation strategies. Besides internal exploitations of technologies, through direct investment in production and/or marketing of products, they identify:

- The creation of innovative firms (units).
- Joint ventures.
- Technology selling (performing contract R&D, licensing out, etc).
- Divestment.

According to Granstrand and Sjölander's (1990) there are moreover other ways in which technology might be used outside the boundaries of the firm, for example when technology leaks to competitors (which might be performing technology scanning efforts), thus causing that the benefits of the technology are not appropriated by the firm.

From this and related typologies, Lichtenthaler (2005) abstracts a more general classification consisting of:

- Collaboration.
- Licensing out.
- Knowledge sale
- Divestment of company units.

According to Lichtenthaler (2005) there are three central managerial issues when commercializing external technology. First, companies need to establish an overall strategy for ETC in line with the strategy for internally exploiting technology and with the corporate strategy at large. Accordingly, the company's competencies and prior experience play a crucial role in profiting from ETC. Second, ETC needs to be managed through a process of planning, identification, negotiation, realization and control, in which the different phases are iterative rather than sequential parts

of the overall process. Third, successful ETC will depend on the coordination and organization of the various tasks and competencies within the overall process. Given the importance of such organization, the process of successful ETC is likely to be of a strategic and proactive nature (rather than an ad hoc operation (cf. Fu and Perkins, 1995; Kline [2003])).

AN INTEGRATIVE MODEL FOR TECHNOLOGY-DRIVEN INNOVATION AND EXTERNAL TECHNOLOGY COMMERCIALIZATION

Based on the various opportunities offered by TDI, this chapter proposes a model for technology-driven product innovation and external technology commercialization. The model not only contributes to and extends the current understanding of the open innovation literature and practices, but it also builds on a number of mainly practitioner-oriented models for managing different stages in NPD (e.g. Cooper, 2000; Hart & Baker, 1994) Hereby, the model presents a comprehensive framework, which consists of practically implementable elements and should thereby offer concrete opportunities for value appropriation through the identification of both internal and external commercialization opportunities. Accordingly, the model has been designed as a practical guide for TDI projects. The model shows the key phases of the TDI process from a practitioner's perspective and it shows at which stages of the innovation process different opportunities for ETC occur.

Current Models for New Product Development

One of the earliest and best-known models of the NPD process is the basic eight step linear model developed by Booz, Allan, and Hamilton in 1968 (Figure 5). This model, however, does not give a

good representation of reality. Hart (1994) argues that the NPD process is not one of consecutive stages or activities, but rather a concurrent process with overlapping activities which require constant feedback and interaction.

The obvious deficiencies of the linear NPD process model have led to extensive research in the area of NPD. This in turn has led to an abundance of NPD process models, among which departmental-stage models, activity-stage models, cross-functional models, decision-stage models, conversion stage models, response models, and network models. Two specific models that will be discussed in more detail are the stage-gate model (Cooper, 1990), because it is widely used by practitioners, and the multiple convergent process model (Hart & Baker, 1994), because it addresses some of the deficiencies in Cooper's (1990) stage-gate model.

The stage-gate model was developed by Cooper (1990) as the conclusion of many years of research into NPD success factors. Cooper himself describes the stage-gate model as follows:

"A stage-gate system is both a conceptual and an operational model for moving new products from idea to launch." (Cooper, 1990 p. 44)

Stage-gate models divide the NPD process into a number of stages and gates. There are usually four to seven gates, depending on the specific project and the firm. During each stage, a specific part of the NPD process is carried out. This should not be mistaken for a single activity or department; a multi-disciplined project team carries out a variety of parallel activities during each stage. The gates

function as decision moments during which the project is evaluated against pre-set criteria. NPD projects that do not meet the pre-set criteria are cancelled or put on hold.

The stage-gate model (Figure 6) has quickly gained popularity among practitioners because it allows firms to effectively structure the NPD process. Furthermore it is an attractive model because detailed criteria at each gate ensure that as development cost increases, uncertainty decreases. Hart and Baker (2008) however argue that, while stage-gate models provide a good roadmap that can be used to ensure that vital activities (especially with regard to market needs) are carried out in a complete manner, the simplicity of the model leads to some deficiencies. Every NPD-project follows a different trajectory, partly based on the type of product and the firm in which it is being developed. Activities are being carried out in parallel, and yet need to converge since they are of direct influence on one another. Additionally, Hart (2008) describes NPD as being an iterative process. Failed concepts may lead to new ideas, and product development may lead to unforeseen market opportunities.

NPD should moreover not be seen as an isolated process carried out within the boundaries of the firm. NPD is a process that takes place within the context of open innovation, both inbound and outbound. Third parties, such as suppliers, customers, end users, and strategic (development) partners need to be taken into account. In the multiple convergent process model, Hart and Baker (2008) show how multiple activities are carried out simultaneously, and how the results of these activities converge multiple times during

Figure 5. Linear model of new product development (adapted from Booz, Allan, & Hamilton [1968])

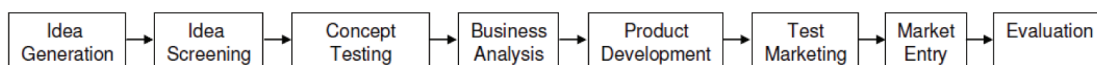
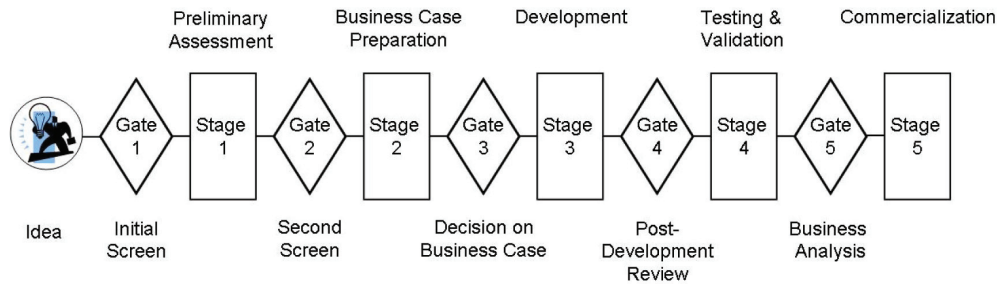


Figure 6. Stage-gate model (adapted from Cooper [1990])



the NPD-process. They summarize the advantages of the multiple convergent process model as follows (Hart & Baker, 2008: 273):

1. Iterations among participants within stages are allowed for.
2. The framework can easily accommodate third parties.
3. Mechanisms for integration throughout the process among different functions are set in convergent points.

While the multiple convergent process model is more comprehensive than the stage-gate model, it also provides less of a functional structure for use by practitioners. The model addresses some of the main shortcomings of the stage-gate model, yet in doing so the practical usefulness of the multiple convergent process model can be questioned. The practitioner model for TDI and ETC presented later on in this chapter will combine the practical aspects of stage-gate models while addressing the main deficiencies that Hart and Baker (2008) noted and tried to resolve in the multiple convergent process model.

New Product Development Models and Technology-Driven Innovation

Generic NPD models as discussed above do not take into account the unique characteristics of TDI projects. Some of these characteristics, such

as a higher degree of market uncertainty, technological uncertainty, and innovation have been discussed earlier on in this chapter. This section will be a further elaboration on how the unique characteristics of TDI projects affect the overall NPD process.

TDI projects require a different approach to achieve successful commercialization than MDI projects, either within the firm boundaries or outside of these. Generic NPD models assume that the input for the NPD process is (at least partly) based on recognized market needs. The input for TDI projects, however, is grounded in scientific or technological breakthroughs and as such is not tailored towards the customer base. The exact customer needs and market requirements thus remain unknown. Veryzer (1998) therefore argues that the early phase of TDI projects should be focused on finding applications which are technically differentiated, instead of creating a product that fits known customer needs better than existing products. Through their research, Song and Montoya-Weiss (1998) show that the success of TDI projects is dependent on different stages of the NPD process, when compared to MDI projects. Naturally, generic NPD models do not account for different determinants of success for TDI projects as compared with MDI projects. Table 3 shows the difference in ranking of the importance of NPD activities for really new versus incremental products.

TDI projects are mostly aimed at developing discontinuous "really new" products. This is a significantly different output than that for MDI projects. As a direct result of this, the effective methods for commercialization also differ. For commercialization within the company boundaries, there is a need to envision, create, and educate the market. As shown previously, TDI projects often also present a multitude of opportunities for ETC. These activities and opportunities are not represented in previously discussed models for new product development.

Based on the deficiencies of current NPD models for the use in TDI projects that have been discussed above, it is possible to set up a number of general criteria for a practitioner-oriented model for TDI projects that includes the possibilities for external technology commercialization. Such a model should:

1. Recognize the different input for TDI projects: *The input to the project is a technological or scientific breakthrough. Initial activities are focused on idea generation, application selection, external scanning for potential buyers, licensees, or strategic partners.*
2. Recognize that NPD is not a process of sequential activities: *Successful TDI projects do not consist of a clearly defined pre-*

terminated set of sequential activities. Since all activities are of influence on each other, there is a clear need for parallel activities, convergence points, iterations, and the possibility to split off promising new concepts during the NPD process.

3. Show that NPD is not an isolated process: *A model for TDI projects should include external networking from the first stages of the NPD project. Since both market and technological uncertainty is high, external information sources and potential development partners should be used in order to decrease this uncertainty. Furthermore, opportunities outside the firm boundaries should be researched in order to find opportunities for sales, licensing or joint ventures.*
4. Allow for regular evaluation moments or convergence points: *The NPD-projects progress should be regularly evaluated. However, extra care must be taken to make sure that projects are not cancelled due to misleading market information.*
5. Recognize that different activities take precedence in TDI projects: *TDI projects have different success factors from regular NPD projects. The process must be shaped to fit these success factors. The model must furthermore recognize that conventional R&D and marketing methods can lead to subopti-*

Table 3. Relative ranking of success determinants in the NPD process (adapted from: Song and Montoya-Weiss [1998])

Rank	Really New	Incremental
1	Product commercialization (+)	Business and market opportunity analysis (+)
2	Strategic planning (+)	Product commercialization (+)
3	Technical development (+)	Technical development (+)
4	Idea development and screening (ns)	Idea development & screening (ns)
5	Product testing (ns)	Product testing (ns)
6	Business & market opportunity analysis (-)	Strategic planning (-)

1 = Most important determinant of success, 6 = Least important determinant of success; (+) = positive effect on success level, (-) = negative effect on success level, (ns) = No significant effect on success level

mal and misleading results, especially when attempts at early customer involvement are made. The model must encourage methods suitable for TDI projects.

A PRACTICAL MODEL FOR TECHNOLOGY-DRIVEN INNOVATION PROJECTS AND EXTERNAL TECHNOLOGY COMMERCIALIZATION

Based on the criteria shown above and the identified unique characteristics of TDI projects, this section now develops a practical model for TDI-based NPD projects, which includes a firm’s possibilities for ETC during the different stages of technology and product development (Figure 7).

The model consists of six development phases and two intersections. The development phases are made up of parallel overlapping activities, and the intersections represent convergence points where the trajectory of the NPD project can be altered. The model was designed to be generically applicable and should be used

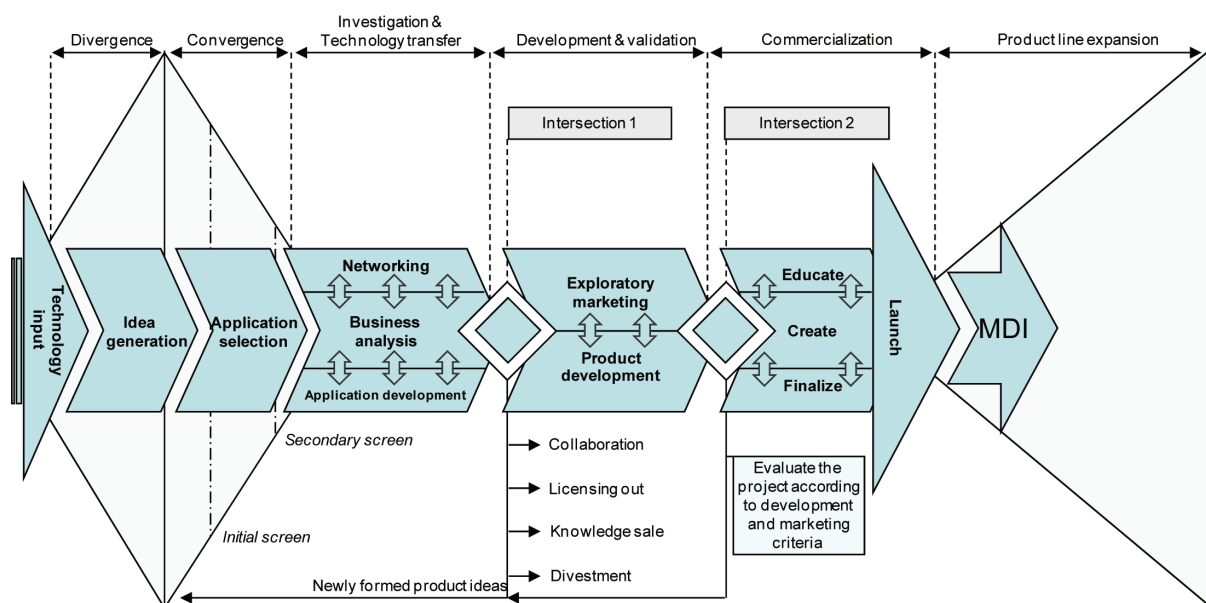
in accordance with a company’s overall new product strategy. Whereas Cooper’s stage-gate model is intended as an operational model for developing new products from idea to launch, this model can be seen as an operational model for driving the development of technologically discontinuous innovation from breakthrough to commercialization, within or outside the firm’s boundaries.

The model shows the phases of TDI projects and which key activities should be carried out during these phases. The model furthermore shows two intersections. The name “intersection” has been chosen because its purpose is different from traditional “gates” or “convergence points” since it includes the possibilities for outbound open innovation or ETC. A more detailed description of the phases and intersections is given below.

Divergence

The NPD process starts with the opportunity to transform a scientific or technological breakthrough into marketable new products, either

Figure 7. Integrative model for technology-driven innovation and external technology commercialization



within or outside of the firm's boundaries. During the divergence phase, idea generation methods are used to create a large amount of product concepts. Already here, an initial distinction can be made between product concepts that fit within the firm's internal new product strategy and product concepts that can be considered for external commercialization.

Convergence

During the convergence phase, the product ideas are screened according to selection criteria set up to fit the company's purposes. In general, there should be at least two consecutive rounds of screening. The initial screening will be based on the assumptions and experience of a multi-disciplinary project team (extensive research being impractical because of the quantity of ideas). Depending on the technology and product concepts generated during the divergence phase, experts from outside of the firm boundaries can already be involved in the screening of product concepts that are being considered for external commercialization. The secondary (and possibly consecutive) screening(s) are based on preliminary internal and external research. Because of the unreliability of market and customer data collected at this point, it is advisable to value the opinions of the multi-disciplinary project team members and internal and external industry experts over collected market and customer data if a conflicting assessment should arise at this point in the process. The convergence phase ends with the selection of the most promising ideas for internal and external commercialization.

Investigation and Technology Transfer

During this phase, business cases for the product ideas are developed, making extensive use of all the firm's networking capabilities. Potential

industries for the product concepts are analyzed and possible routes towards internal and external commercialization are considered and compared. During the phase, the technology transfer from breakthrough technology to application prototype also takes place.

Intersection 1

At the first intersection the results of the previous phases are evaluated for each product concept in order to decide upon the further trajectory of the NPD project. Instead of a standard "Go/No Go" decision, the following options are considered:

- Continue in-house product development activities
- Establish a collaboration for further development
- License out the IPRs to an interested external firm
- Sell the acquired knowledge to an interested external firm
- Divestment of the company unit affiliated with the product concept
- Shelve the product concept for possible future continuation (not shown in the model)

It is important to note that these possibilities are not mutually exclusive. For example, there can be strategic considerations for commercializing a new technology both within and outside of the firm boundaries. Examples include the possibility to benefit from cross-licensing agreements or an attempt to establish industry standards (Lichtenhaler & Ernst 2007).

New product concept ideas often arise during the different stages of the product development process. It is important that these ideas are documented so that they can be considered at a later stage for possible development and commercialization. Both intersection points serve as organized intervals in the product development

process where new ideas are aggregated, documented, and sent on for screening or immediate further development.

Development and Validation

The development and validation phase is started if the firm has chosen to continue in-house development activities. During this phase the application prototype is further developed into a functioning product prototype. In order to fit the product that is being developed for the intended market, exploratory market research is carried out. The exploratory market research must consist of methods that are appropriate for TDI projects. Which types of methods are most applicable is dependent (among other things) upon the intended target customers and the ‘newness’ of the market. Since market needs and customer requirements can often not be accurately measured in existing markets, this is a process of “envisioning” the market.

Intersection 2

At the second intersection, the project is evaluated according to pre-set development and marketing criteria. This intersection is then also used to decide upon the further trajectory of the project. The decision can be made to extend the project in-house into the commercialization phase, or any of the trajectories summed up at intersection 1 can be taken to pursue ETC. Thus, again there is the possibility to choose several paths for commercialization both within and outside of the firm boundaries. If a product concept at this point does not meet the pre-set marketing and development criteria and no attractive opportunities for external commercialization are available, there is also the possibility to discontinue development and shelve the product concept for possible future continuation.

Commercialization

The commercialization phase consists of four key activities, namely creating market demand, educating the target customers, finalizing the product, and launching the product. The first three activities are carried out in parallel and should exhibit a considerable overlap with one another. The product launch can be carried out both during or after these activities, depending on the product launch strategy. For example, when choosing the probe and learn approach all four activities will be carried out simultaneously (Lynn et al., 1996).

Product Line Expansion

The model has been developed to guide the successful commercialization of technology-driven innovations both within and outside of a firm’s boundaries. After this has been achieved, market-driven innovation approaches can be used for further incremental innovations and product line expansions. Opportunities for external commercialization can still present themselves after the product has successfully been launched within the boundaries of the firm. Whether or not to pursue these opportunities is dependent on the firm’s strategic objectives.

CONCLUSION

ETC is an increasingly important type of open innovation (Chesbrough, 2003; Lichtenthaler & Ernst, 2007), which is however not yet fully understood (Enkel et al., 2009; Bogers & West, 2010). Moreover, firms practically need to consider under which condition they should pursue either internal or external commercialization of technology-driven innovation. This chapter therefore develops an integrative model for internal and external technology commercialization, based on extant literature and frameworks in the areas of innovation, TDI, and ETC. Thereby, this

chapter provides a holistic understanding of what it takes to successfully commercialize technology, either through internal or external commercialization paths. The model presents various phases in the process of commercializing technology (divergence; convergence; investigation and technology transfer; development and validation; commercialization; product line expansion) and presents the relevant intersections, which provide the alternative commercialization paths. Hereby, this chapter provides a holistic perspective and a practical tool that assists managers in finding the most viable commercialization opportunities, which might often lie outside of the boundaries of the firm.

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KEY TERMS AND DEFINITIONS

Commercialization Phase: The commercialization phase consists of four key activities, namely creating market demand, educating the target customers, finalizing the product, and launching the product.

Convergence Phase: During the convergence phase, the product ideas are screened according to selection criteria set up to fit the company's purposes.

Development and Validation Phase: The development and validation phase is started if the firm has chosen to continue in-house development activities. During this phase the application prototype is further developed into a functioning product prototype. In order to fit the product that is being developed for the intended market, exploratory market research is carried out.

Divergence Phase: During the divergence phase, idea generation methods are used to create a large amount of product concepts. Already here, an initial distinction can be made between product concepts that fit within the firm's internal new product strategy and product concepts that can be considered for external commercialization.

External Technology Commercialization: The process of finding commercialization opportunities for internally developed technologies and related developed intellectual property rights outside the boundaries of the firm.

Internal Technology Commercialization: The process of finding commercialization opportunities for internally and externally developed technologies within the boundaries of the firm.

Investigation and Technology Transfer Phase: During this phase, the business case for the new product concept is set-up, while the feasibility of the technology transfer towards a 'real world' application is tested.

Market Uncertainty: The extent to which market related factors are unknown and difficult to acquire during the innovation process.

Market-Driven Innovation: Latent, unsatisfied customer needs in the market place are the starting point and driving force in the innovation process.

Technological Uncertainty: The extent to which the feasibility and required effort of developing a technology into a real world application is unknown.

Technology-Driven Innovation: A new technology, scientific breakthrough, or a combination of new technologies is the starting point and driving force in the innovation process.

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