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Commercialize Technology Assets Comprehensively A Case Study for Automated Tissue Engineering

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Abstract- Competition has become increasingly technology based. From an economic perspective, the value appropriation of technologies is an essential part of technology management. While most industrial firms focus on the internal application of technologies in their own products and services, the external mode of technology exploitation, i.e. the commercialization of disembodied technological knowledge, has long been neglected. This is due to the fact that companies lack in a systematic approach to evaluate their technologies in terms of all available exploitation opportunities.

The goal of the present paper is to propose a new approach for a decision making model to identify the appropriate exploitation strategy considering the key internal and external factors characterizing the commercialization situation. Therefore, a target system for technology exploitation is established and the contribution of the different exploitation strategies, such as spin-off, joint-venture and licensing to the different targets is evaluated. Afterwards the influence of the characteristics concerning market, exploiting company and technology is discussed. The decision making model is developed and applied on the case "Automated Tissue Engineering on Demand", which has been accomplished by the Fraunhofer Institute for Production Technology IPT. The aim of the project was to identify the company and technology specific exploitation strategy for a production facility capable to automatically produce tissues on demand for toxicity and efficacy testing. The presented research in this paper serves as a basis for the development of a web-based technology transfer platform within the Cluster of Excellence "Integrated Production Technology for High-Wage Countries".

Keywords- *technology exploitation, technology commercialization, technology deployment, technology transfer.*

I. INTRODUCTION

In the mid-20th century, the boards of many enterprises were following the philosophy that their own research and development units had to provide the majority of the necessary technologies for the development, production and marketing of their products [1, 2]. As a result high development and manufacturing capabilities were established, which in some cases have led to the phenomenon that certain technologies were only available for a single company or industrial sector [1]. The need to exchange technologies was rather rare.

A. Product complexity requires many technologies

The increasing product complexity eventually resulted in using more and more technologies for only one marketable product [1]. Combined with the emerging cost and performance pressure within the global competitive arena, many companies were forced to focus on those activities that distinguished them in quality and economical aspects from other competitors [3, 4, 5]. The complementary technologies were increasingly acquired by suitable technology suppliers [6]. The core competence approach had developed to be the prevailing management philosophy. Outsourcing-activities became part of most of the restructuring programs. In consequence the rate of internal development and manufacturing activities finally decreased. The procurement activities became an important component of the enterprise function [7, 8, 9]. As a result, the existing markets as we know them today with the processes of exchanging technologies between companies established [10, 11, 12, 13, 14, 15]. Driven by globalization and technological specialization the amount of intellectual property rights increased and promoted the industrial transfer of knowledge [5]. Property rights are insurmountable for providers of products who use the same technologies as well as for companies who are looking for technological solutions that are already developed. They had to deal with property rights that were hardly to handle especially within a short period of time. The exchange of technologies presented itself as the right method. In particular for companies which foster r&d investments [5]. The so called technological markets will gain importance in the future simply because of the better communication and networking possibilities [16, 17, 15]. This is shown in the extension of private and public exchange offices as well as in the publicly financed programs that continuously support industrial technology transfer [5]. The increasing fragmentation of the market however results in a heightened coordination, which led to rising transaction costs [18, 15]. Therefore the advantages of specialization only

reduced partially the R&D costs. The expenses for technology development are still rising especially in high wage countries such as Germany where research constitutes a fundamental important role.

B. Increasing r&d expenses and shorter lifecycles

Even though there are conflicting priorities of increasing cost and performance requirements in complex development networks, financial investors still demand an average of four to six percent organic growth per year [2]. Globalization had an increasing effect on the intensity of competition, which forced the companies to establish new products on the market in an even shorter amount of time [19]. That means increasing innovation cycles on the one hand, while decreasing product life cycles on the other [5, 1, 10, 20, 19]. A consequence is that the products maintain even younger [16]. The shorter product life cycles also cause a contraction of the technological life cycles. Many companies face the problem that there is less time to amortize the high expenses of technology development and that it is even harder to materialize the high profitability requirements of financial investors [21, 5, 16, 10, 22, 19].

C. The limited effect of property rights

Furthermore the commercialization becomes even more important because of the limited effect of legislative and technological measures to protect the new technologies and products [19, 23, 5]. There are some practical examples showing that the copy of new technologies by the competition cannot be prevented simply through property rights. The competition will copy the technology by other products at a given time and launch it at significantly lower costs due to the less R&D expanses [19, 23, 24]. Companies from emerging markets, in particular, can furthermore benefit from the lower labor costs which may displace the products of the inventor very quick [19]. The periods to launch unique technologies are getting shorter. To market technologies also outside of the own company becomes a key to ensure the companies' strategic and financial success [5].

D. Technologies are not fully exploited

Beside the difficulties to generate an attractive return for developed technologies, there are other technologies that are not getting commercialized because of the missing strategic relevance for the company or inadequate evaluation of the technological performance [19, 5, 21, 6]. In many cases the exploiting company is restricted to its own financial woes or production capabilities which may prevent to fully exploit the technology [19]. Furthermore, one company may not be able to capture all the markets through its own production since there are sophisticated import and local content restrictions [19].

According to the Institute for German Economy (IWD), for example, patents often remain unused and are not fully exploited [25]. Alone 98.600 patents are not being enforced and disappear in the company's desks, even though 55.8% of them are ready for implementation [25]. One unused patent has an average value of 146.980 Euro which could be materialized each year. Subsequently a total of at least 8,09 billion Euro of market potential remain unused each year in Germany [25].

E. Technology potential has to be fully absorbed

Companies need to systematically absorb the specific technology potential. They have to develop and implement an exploitation strategy, which in consideration of the chances and risks of the available possibilities of commercialization, attain an overall optimum in technologies exploitation. The commercialization has to go far beyond the usual marketing for their own products, processes and services [1, 19]. It is rather a process of using the different exploitation options to the fullest and leveraging the technology potential. In this way the companies can maximize their return from the increasing expenditures for technological developments [26, 27, 9, 19]. The better exploitation of technology potential and risk diversification to multiple applications of various industries lead to a higher attractiveness of investments in technologies by financial investors and to an improved refinancing rate of the company [1, 28, 29]. There are two fundamental strategic policies for the commercialization of technologies: the internal and the external technology exploitation [16, 21, 23]. The internal technology exploitation focuses on the use of unique technological skills for the products and processes of the own company. By doing so, the goal is not only to gain a comparative advantage for the own products, but also to achieve the broadest possible use of technologies for various products, processes, new sales markets and industries [22]. Though, internal technology exploitation is not the only cause for technological success. It is rather a key to consider alternative reprocessing routes [30]. External technology exploitation is one of those possible routes [31, 32], in which the companies transfer technologies to third parties. The intention of this strategic policy is to gain or to extend comparative advantages with their own technological position of success [27]. The demand for technologies that are ignored in their own production can be stimulated. On a secondary level, selling technologies means that there is a financial gain or a profit return. The focus of this strategy is on the introduction of financial flexibility.

F. Theoretical research question

Within the scope of the acquisition of new technologies, the transfer of technologies into the company is for the own production and services a question that has been intensively discussed, as well as widely appreciated by the technology management community [33, 34, 35, 36, 37]. The question about how to use further exploitation potential with the existing technologies is less discussed [33]. Especially the complexity of the decision making situation, in which one of the various options for exploitation of a certain technology should be chosen while considering internal and external key requirements, is hardly debated in the literature. Researching the driving and the braking forces of the ever increasing technology markets, Arora, Fosfuri and Gambardella demonstrate the need to utilize transfer opportunities, in order to eliminate inefficiencies within the market [6]. Although focusing mainly on licensing as additional form of technology exploitation, they also mention the requirement for further research to identify comprehensive exploitation strategies that respect the implications and correlations of all available exploitation options [6]. In his work, published in 1991,

Wolfrum already points out that the difficulties of decision making to indicate the way of exploitation has to be established in today's literature [21]. He recommends including the wide range of alternative and mutual options to exploit technologies into the company's strategic plan [21]. Ford confirms Wolfrum's argumentation with the statement "What is required is a new approach to strategy formulation which builds on analysis and development of company's technological core. Technologies must form the building blocks of strategy, not just products and markets. A fresh orientation is also required from marketing. It must see its role as the optimum exploitation of company's products and production technologies throughout their life cycles by integrating all available exploitation methods" [38]. To support companies in the complex situation of keeping or selling, Lichtenthaler, Birkenmeier and Escher emphasize the need to research the development of management tools in technology exploitation [1, 15, 16, 33].

G. The definition of the challenge in practice

Successful companies like IBM, Xerox, Dow Chemicals, Texas Instruments, Honda, Nelm or Procter&Gamble already realize some of the enormous potential inherently provided by the comprehensive commercialization of already developed technologies [33, 20, 26, 1, 15, 26, 14]. Those companies do not only focus on the use of their own technologies for their own production, they also benefit from internal and external commercialization opportunities [21, 15]. Estimations by some sources say that the USA has annual license revenue of $15 billion in 1991. In the year of 2002 it has been supposed to be already at $100 billion [15, 39]. The company Texas Instruments generates revenues of 50% through licensing for several years now [33]. Procter&Gamble only uses 10% of the already developed technologies for their own products. Therefore there is a huge sales potential for Procter&Gamble if they start using their unused technologies outside of the own production [33, 2]. Motorola's external exploitation of mobile technologies achieves estimated revenue of 10 billion US Dollars [33]. The figures show the enormous potential of comprehensive internal and external technology commercialization. Many companies, however, have problems to adapt the successful approaches [40, 41]. Even though many of them are willing to utilize their technologies internal as well as external, most companies cannot manage to reach the potentials of an all-embracing exploitation for their business [33, 10]. What is missing is a management guide to support the companies in their decision whether or not selecting an exploitation option [1, 16].

II. AIM OF THE PAPER

Therefore, the aim of the present paper is to propose a fundamental approach for a decision making model to identify the appropriate exploitation strategy considering the key internal and external factors characterizing the commercialization situation. The evaluation of the decision making concept is based on a throughout analysis of the existing literature and one case which has been accomplished by the Fraunhofer Institute for Production Technology IPT. The goal of the case was to identify the appropriate exploitation strategy for a production facility capable to automatically produce tissues on demand for toxicity and efficacy testing. Based on this fundamental analysis, a decision making model is proposed, in which are considered a comprehensive perspective of the different exploiting strategies and the key interdependencies of the commercialization situation. The decision making model is developed and applied on the case "Automated Tissue Engineering on Demand", which has been accomplished by the Fraunhofer Institute for Production Technology IPT. The aim of the project was to identify the company and technology specific exploitation strategy for a production facility capable to automatically produce tissues on demand for toxicity and efficacy testing.

III. RELEVANCE IN LITERATURE

In the 1970's, the need to commercialize technological know-how in a systematic and comprehensive way was shown for the first time. Especially the introduction of the term technology marketing by Ford led to a first approach on technology exploitation [42]. In consequence, many investigations with a strong focus on the commercialization of technologically-oriented products were published in the field of technology marketing. Furthermore, some authors subsume the two core activities – technology acquisition and technology exploitation – under the term technology marketing. As it was presented in the introduction of this paper, the active and systematic technology exploitation received, so far in practice, too little attention. Therefore, it is no surprise that only a few approaches on internal and external exploitation of technologies exist in literature. Especially the decision making process to select the appropriate exploitation option by considering the special characteristics of the deploying situation are only sparsely discussed in literature. It seems that especially the interdependency of the various influencing factors of the exploitation situation have are too complex to be analyzed comprehensively in order to support the decision making in technology exploitation.

A. Ford and Ryan 1977

"[…] a company's technology is unlikely to be fully exploited simply by its in cooperation in products and services alone. [Ford and Ryan] present an exploratory study of the problems which can arise during the marketing of know-how" summarizes the editor's note [42]. The paper of Ford and Ryan is the first one which addresses the challenge of technology marketing. They state that the exploitation of technology is mainly linked to the exclusivity and non-exclusivity marketing of company's technology. Hence non-exclusive know-how marketers prefer to include companies whose main business is in the sale of tangible products and for whom the sale of know-how is not part of their main business model [42]. The paper focuses mainly on non-exclusive technology marketing and distinguishes the analysis furthermore between mainstream and by-product technologies [42]. The characteristic of the technology and the company's business model are understood as an important factor for the exploitation decision by Ford and Ryan. In addition the paper discusses different ways applying the available know-how even though they are not considering the typical exploitation options such as spin-off, joint-venture

or licensing. In this understanding the know-how can be applied in the different ways: providing a product, facilitating a product, non-profit use and market as know-how [42]. Given the different ways of applying know-how the authors moreover discuss the difficulties coming along with technology marketing [42]:

- Intangibility leads to problems in both service and know-how marketing [42]. Ford and Ryan point-out that know-how as a service is hard to explain to an external customer, but also not easy to identify within a company especially due to know-how intangibility [42]. Only few companies do not consider the know-how application in their strategy nor do they have any scanning mechanism to make use of the possibly available know-how [42].
- Buying technology know-how is accordingly often accomplished by engineering staff. Probably the same people which may have failed to develop the know-how internally [42]. These individuals are obviously reluctant to pursue the acquisition of this technological know-how. Therefore the technology acquisition of the buying company needs to be addressed by an appropriate level within the company [42].
- Distribution of technology know-how is much different from transferring physical products. Whereas delivering tangible products can be measured by data given, know-how is transferred by so called semi-continuous communication [42]. Especially the service provision is difficult to define due to the associated legal issues. Franchising could support a standard technology marketing of intangible assets, also fostering the continuous sale of raw materials used during the exploitation of the know-how [42].
- Market identification for know-how marketers seems to be a major difficulty. Common standard marketing activities such as test-marketing can often not are applied considering the high confidentiality [42]. Moreover the timing of transferring the know-how is often failed. Companies tend to sell a technology too late because they lack in market information [42].
- Pricing is the most complex question in technology transfer [42]. Ford and Ryan suggest different ways to calculate the market opportunity, but still emphasize that only less companies are capable to process this on a regular basis. That's way so called middlemen are included in the deals to support the negotiation of technology acquisition [42].

The paper of Ford and Ryan point-out the need to exploit technologies comprehensively for the first time in literature. They mention different exploitation methods for intangible know-how and describe the problem coming from different influencing factors. The discussion about different influencing factors such as price, market identification, distribution, buying, and intangibility can be used and further developed. However, independencies between the different characteristics of the exploitation situation and the generally available ways of exploitation are not considered.

B. Ford and Ryan 1981

The contribution "Taking Technology to Market" is motivated by the high R&D costs, competitive pressure from low-cost producers, capacity limitations, antitrust laws, financial difficulties, and foreign trade barriers which do not allow anymore to solely commercializing technologies in product sales [19]. In the understanding of the authors, the technology life cycle concept "…can help companies [to] decide when, how, and whether to sell their know-how" [19]. So the authors focus on the problems coming along with technology sale, dealing with the risk losing the company's "seed corn", the process and timing of technology sale, and the impact on the company's internal product portfolio [19]. Therefore they particularly use the technology life cycle as conceptual framework to discuss the challenge of technology exploitation. Ford and Ryan describe the different stages of the life cycle model and emphasize the need of different thinking in each stage.

Ford and Ryan demonstrate the strategic advantage to license and sale intentionally in an early phase of the technology life cycle [19]. In particular, the customer's feedback for a technology in an early stage can boost the own experience for later product market launch and lower the development costs [19]. A cold assessment is needed in each stage of the life cycle to decide whether the sale or license of a technology is beneficial to the company [19]. The company should access the market size, the requirements of technology leadership and the potential to establish a standard [19]. If the global market size exceeds the company's capabilities to exploit quickly enough licenses can support wider market coverage [19]. Moreover, the willingness of a company to share the technology could decrease the interest of competitors to develop their own technology. Setting a standard is definitely an advantage of the first market player, but in later stages there are alternative technologies under development by the competitors [19]. The decision to sale a technology during the phase of application growth seems to be most difficult because the company has achieved first success in product sales. Thus arguments within the company are likely to delay the sale of technology to a later stage where the value of the technology already has decreased. Timing, hence, is a very crucial factor [19]. The paper of Ford and Ryan gives some very interesting starting points to evaluate a full exploitation of technologies. In particular the technology life cycle concept seems to be an adequate framework to analyze the exploitation options dynamically over time and application potential. Moreover the paper discusses some very first evaluations in which stage of the life cycle concept an additional external deployment of the technology the company can benefit most. On the one hand, accordingly, technology sale and licensing in an early stage of the life cycle seems to be more beneficial to the seller due to the important early customer feedback and additional financial flexibility while there are less buyers of the technology because of less confidence in the maturity of the technology. On the other hand, technology sale and licensing in a late stage benefits form the acceptance of the buyer due to the already achieved success of the technology, but there will also be available competitive technologies which lower the value of the exploited technology. However, the most crucial stage for

external technology deployment seems to be the phase of application growth, even though the decision making is very tough. Finally, Ford and Ryan emphasize that the management of technology exploitation needs to be driven by a coherent development strategy for full portfolio of technologies, awareness of the value of developing technologies without incorporating into products, special marketing staff, and external middlemen which help to moderate the buyer-seller interaction [19].

C. *Mittag 1985*

Mittag's detailed research is helpful to further develop a decision model in technology exploitation. In the present paper, however, the drafting and implementation of an exploitation option are not the most important aspects; it is rather about the selection of a matching option of exploitation. Mittag's approaches considering the different technology features still can be adopted in the customer's model in order to use it for the technology model and the licensee's characterization. The orientation towards the company specific exploitation objectives is not sufficiently addressed. Although Mittag describes the motives of licensing with regard to sales and procurement, he does not derive them from a superior decision entity, for example like the strategy of the technology and the company. Subsequently, he abstains from the description of the effects of the different targets on the drafting of the licensing, because of his prior focus on the positive effect of licensing as an instrument for market cultivation [5]. On the one hand the extensive analysis of licensing is a pioneering force to describe other exploitation options; on the other hand, concerning the contents, it indicates the strengths and the weaknesses of licensing as an individual exploitation option.

D. *Ford 1988*

Ford's paper is motivated by the lack of strategic thinking with regards to product and production technologies [38]. Hence, the technology strategy has joined "[…] the ever-lengthening list of concerns […]" which has to demand high attention of senior managers [38]. Accordingly, a technology strategy consists of policies, plans and procedures to acquire knowledge and abilities, managing the knowledge and abilities within the company and successfully exploiting them with appropriate profits [38]. While describing the audit to develop a technology strategy, Ford is reflecting different questions which should be answered during the strategy formulation [38]. Much attention is given to the management and acquisition of technologies, but also technology exploitation is emphasized in the discussion. "Does the company achieve the optimum exploitation of technologies we have?" states the starting question of Ford's decision model to fully exploit technologies [38]. In this very first attempt to develop a decision model, Ford considers the four different exploitation methods "Employ in own production or products", "Contracted-out manufacture or marketing", "Joint-Ventures" and "License-out" [38]. These different exploitation methods are then assessed in terms of the seven different influence factors "Company's relative standing", "Urgency of exploitation", "Need for support technologies", "Commitment/ Investment involved", "Technology life cycle position", "Categories of technology", and "Potential application" [38]. According to the evaluation of Ford (see Figure 1), a successful licensing-out requires a very good (high) standing of the exploiting company, which refers to the acceptance in the market, compared to its competitors [38]. In contrast, an internal application should applied first, if the acceptance of the exploited technology or products is not well established, and therefore needs to be proved though internal application [38]. However, a quick exploitation is essential to generate quick wins by first financial returns and moreover to prevent competitive technologies to catch-up. This can be most likely realized by licensing-out the technologies in an early phase fostering customer's feedback and competitive advantage through standardization [38]. Furthermore, a newly developed technology may need complementary assets, such as marketing skills for successful market penetration [38, 43]. These complementary assets are more likely to be acquired through "joint-ventures" or "contracted out manufacture or marketing" [38]. Column four and six indicate the commitment involved in the newly developed technology. For the companies most distinctive technologies, which are often the technologies with the highest investment involved and therefore the company's seed corn, internal application seems to be more likely to be the best method of exploitation [38]. At least in an early stage of the technology's life cycle, company should resist to license-out or sale the technology in order to ensure that their position of strength is not diluted through leakage to others [38]. Finally, the width of technology application is a very important factor to exploit the technology. The wider the applications of the technology, the more valuable are licensing and joint-ventures to fully exploit the technology [38]. Ford argues that a wider range of application may also increase the demand for support technologies or complementary assets, higher investments and higher knowledge of different markets the company may not be familiar with [38].

Exploitation methods	Company's relative standing	Urgency of exploitation	Need for support technologies	Commitment / Investment involved	Technology life cycle position	Categories of technology	Potential application
Employ in own production or products	lowest	lowest	lowest	highest	earliest	most distinctive	narrowest
Contract-out manufacture or marketing	lowest	high	high		early		narrow
Joint-Venture	high	low	high		early		wide
License-out	high	highest	low	lowest	later	Least distinctive	widest

Figure 1. Ford's factors affecting technology exploitation decision

Ford's decision model for exploitation states a first major approach to describe the complex decision situation in terms of technology exploitation even though not all exploitation methods are considered and some essential influences such as potential market and company's character are missed. However, the understanding developed by Ford is trend-setting and will be adopted in this paper.

E. *Wolfrum 1991*

The approach developed by Wolfrum provides an overview of the problems of decision making in technology exploitation. He takes the main exploitation options such as licensing, joint-venture, spin-off and R&D cooperation's into account, considers them on a generic level without paying attention to

the combination possibilities. His accomplishments on various exploitation options can be included in the present paper. His argumentation of the interdependences between different aspects of decision is from very high value. At this point he addresses the issue of various interactions between the characterization of the technology and the selection of the exploitation option [21]. The approach shall be added and extended in the present paper in comparison with the technology model and the sub-model exploitation option. The author points out the need to consider the company specific targets as well as market and company specific strengths and weaknesses while being in the complex situation of making a decision. Despite of that, he renounces explaining their interdependences in further research to foster a comprehensive investigation of technology exploitation. In summary, it is proven that Wolfrum's argumentation is of a high value for the following development of the decision model, since he points out the first interdependences of the complex situation of decision making, which can be adopted in a situational decision model that serves the selection of an exploitation option.

F. Boyens 1998

Boyens' work provides a valuable contribution to the qualitative evaluation within the exploitation situation, although just a few relevant influencing variables can be simulated. Boyens only differentiates between internal and external technology exploitation, but renounces to describe the different exploitation options in detail. The relative profitability of the external to the internal exploitation is calculated on the basis of three relevant influencing variables. In comparison to other previous decision models that means a significant development [44]. The present paper also includes a strongly qualitative evaluation of the different exploitation options, which means that Boyens' approach can be used for further developing of the decision model.

G. Sullivan 1998

Sullivan developed a questionnaire to technology exploitation and embedded it into a decision tree, which is similar to the procedure of Teece. Questions about IP protection of innovation, relevance to competition and competitive position, the need for complementary skills and the ability to create these by one [45] are all considered. In general, this decision methodology is better evaluated than Teece's, because on the one hand, the exploitation options are explicitly mentioned, and on the other hand occurs an allocation of the respective exploitation options at the nodes of the decision tree. It remains unclear, however, for which form of joint use should be striven, as joint venture and strategic alliance are identified as equivalent solutions for the case of lack of skills. In addition, similar to Teece's work, the focus is put heavily on the complementary skills, while other characteristics of technology, market or also of company are neglected.

Ultimately, this model seems therefore only a very rough support for a valid decision about the technology exploitation, because too many situation-specific factors as well as possible interactions are not taken into account.

H. Ford and Saren 2001

Ford and Saren try to map the decisive situation in exploitation in their contingency model and provide a valuable contribution to solve the problem of decision making. However, the model does not fulfill the demands for complexity and the dynamics involved. The different interdependences between each factor are not considered while selecting the exploitation option. Furthermore it involves mainly technical criteria, which excludes a range of other variables of impact. Targets or market characteristics are not included in the decision making, although the authors refer to the comprehensive analysis of internal and external factors [46]. In general, Ford's and Saren's work is a helpful support to generate a comprehensive methodology to select the matching exploitation option.

I. Birkenmeier 2003

Birkenmeier established a management framework which can be adapted for the present work. Regarding the decision making situation, it can be stated that Birkenmeier describes the external technology exploitation as an independent option of operation. He also describes the interdependence between the specific characteristics of a technology, the company and other contextual factors. Thereby, the author provides an approach that enables drafting the decision model by the means of the situation. However, Birkenmeier renounces considering internal exploitation as a strategic action parameter, as well as considering the interdependences of the various exploitation options (joint-venture, spin-off, licensing, sales etc.). But in his further research he states that additional investigations are needed in order to develop instruments for systematic technology exploitation, and therefore facilitate the safe handling of the complex task of managing technology exploitation.

J. Escher 2005

Due to extensive case studies and literature research, the investigations made by Escher are helpful for the present paper. Escher's dissertation makes a major contribution to the company specific concept of the processes and the structures of external technology exploitation. Although Escher explicitly mentions the keep-or-sell decision in his model, he abstains from going into details of the decision situation and also ignores the specific features of the various options of action in exploitation. The company's classification established by Escher to manage the organization and process model can be relevant for the present paper [1].

K. Lichtenthaler 2006

In his paper, Lichtenthaler develops a theoretical management concept which takes a holistic perspective. For the investigation of the external technology exploitation this is a valuable groundwork. The empirical investigation of 154 companies was able to demonstrate the current state as well as challenges of external technology exploitation in implementation [15]. Lichtenthaler's studies are helpful for the

present paper in order to embed the keep-or-sell problem in a holistic frame. The company specific decision making situation, which is supposed to help linking technologies with exploitation options, is not made a subject of discussion.

L. Schuh and Klappert 2011

The comments made by the authors can be further developed in the present paper. The technology specific evaluation of the bundle of exploitation options could serve as an approach for the comparison of the technology and the strategy model [47]. Nevertheless, the abstracted views of bundles of exploitation options have to be reduced to a single meaningful option. The description of the chances and the risks of the internal and external exploitation also can be used in order to develop an evaluation of the various exploitation options. However there are only a few starting points to evaluate the options of exploitation with regard to the company and the market.

M. Summary and deficit of the state of the art

In summary, it is possible to observe that the existing approaches in the literature address only partially the complex decision problems of technology exploitation. Many contributions mention the decision situation as an integral part of their process models, but without a detailed examination and evaluation of different exploitation options. Other publications accompany the decision and focus mainly on the development of a design model for the management of the technology exploitation task.

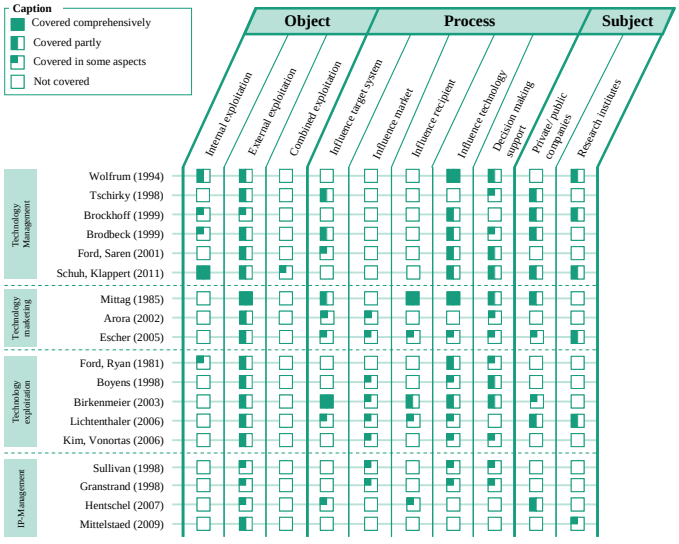

Figure 2. Overview of literature decision making in technology exploitation

These preliminary considerations in literature can be applied in this work, mainly to identify different influencing variables and characteristics. Some of the existing articles also include a detailed analysis of the opportunities and risks of isolated exploitation options, which can also be used in this work. The decision models from Ford, Teece, Sullivan, Boyens and Wolfrum offer concrete starting points for the present paper, which can be incorporated in each part of the decision making framework. This refers in particular to the structure of the technology model, of the sub-model about exploitation options and the selection model for exploitation options. Unfortunately, in the existing models are often considered only a few parameters or the decision task is simplified to a few exploitation options. Interactions between different factors that influence the available technology exploitation options are not sufficiently considered. In sum, it can be concluded that the state of the art offers initial approaches for the solution of the decision task, but does not provide comprehensive decision support. The existing approaches are developed in this work to a holistic problem-solving approach.

IV. CONCEPTION OF THE APPROACH

According to decision making techniques, the solution of a complex decision problem requires specific objectives that serve as an orientation for selecting one of the alternatives [48].

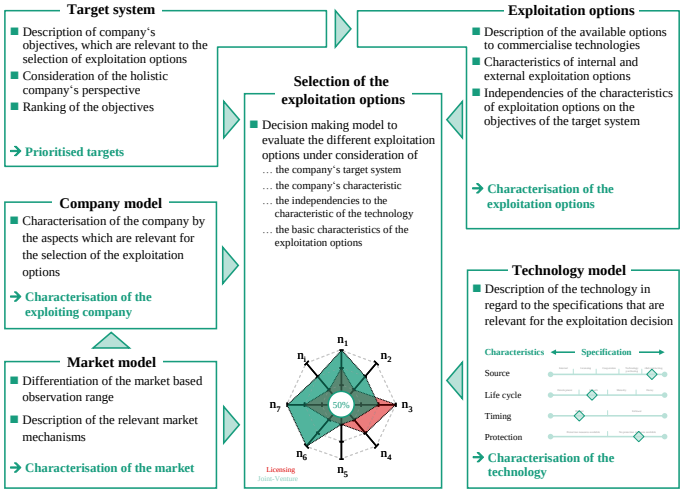

Figure 3. Holistic decision making model of technology exploitation

Therefore, a system that represents the company's targets as well as their options of exploitation constitutes a part of the approach to solve their decision problem (cf. picture 3-1). Referring to the thoughts of Wolfrum, Szyperski, Mittag, Ford, Birkenmeier and Boyens, a technology model has been included as part of the approach (cf. 3-1), because the characteristics of the technology have an essential impact on the exploitation decision [44, 46, 21, 5, 16]. Using a technology model guarantees a decision that considers the specific characteristics of the exploited technologies. Among his colleagues, Escher emphasizes the impact of the company's specific characteristics regarding the selection of the exploitation options [1, 21, 16, 5]. This is why a business model has also been added to the approach (Figure 3), which marks the specific situation of a company on a certain market. The basic idea for considering a business model is the company specific alignment of the whole approach. Ford, among most of the other authors, emphasizes the impact of the external market conditions on the decision making situation [46, 21, 16, 1, 44], which is the reason for adding a market model to the present approach (Figure 3). On the one hand, it limits the selection of an exploitation option to a certain market; on the other hand, it

describes the underlying market mechanisms. It leads to the addition of the specific situation of the company into the exploitation decision. In the light of the various forms of technology and target systems, an evaluation of the available options of exploitation in the selection model has been made under the influence of aspects concerning the exploiting company in the relevant market. Therefore, the selection model has been included into the approach (Figure 3). The models results are evaluated exploitation options that are accordingly to their contribution to the target system in consideration of the essential internal and external influencing factors.

In the following section the single sub models are going to be specified. While describing the objectives of every sub model individually, there are also approaches to flesh them out. Subsequently, the grey boxes at the end of each description illustrate the sub models with examples. The on-going research and development project "Automated Tissue Engineering on Demand" is continuous used as an example. This interdisciplinary Fraunhofer project implies the development of a production plant that automatically produces human skin. While working on that project, the question arose about how the already developed technologies are going to be utilized. This problem can also be seen as the central business challenge for the success of the project. Because of the missing information and tools in the available literature as well as in the practical field, a pragmatic approach was developed that finally led to the decision to spin-off a new company simultaneously with licensing the technology.

A. The target system

The target system is composed of plenty variables that are relevant to the decision making, which have to be broken down out of the superior ones. Targets from related disciplines like production, marketing, sales and procurement have to be reviewed with regard to their relevance for the exploitation target system. Mittag separates the exploitation objectives in selling and purchasing policy targets [5]. The first refers to the increase of sales profits due to the commercialization of the technology to support the product marketing or to commercialise those products that have not been used yet [5]. The latter contains the access to new or economically not accessible know-how [5]. Brodbeck suggests aligning the exploitation to the economic and strategic objectives. The economic objectives are divided into performance, timing and revenue targets [22]. Performance goals include the estimated number of applications and their demands on quality [22]. The timing targets determine the duration and the date of the exploitation, while the revenue objectives consider the desired amount of monetary remittances. Birkenmeier confirms those objectives by mentioning them to achieve efficiency. However, the exploitation decision should not be made only by judging the efficiency. A decision based on that context could lead to undermining the technological foundation of the company [22]. Brodbeck acknowledges the fact that the exploitation decision is influenced by other factors within the company [22]. So he recommends the consideration of strategic objective in the exploitation decision in order to see, from a point of view that aims for efficiency, if the decision benefits the entire company [22]. Birkenmeier suggests the consideration of business oriented variables of the product- /market expansion grid according to Ansoff as well as targeted competitive strategy variables referring to Porter [49, 50]. Furthermore, Mittelstaedt includes a communication target to exploit technologies. According to that the superior objective of technological know-how is to optimize the performance in order to evoke enthusiasm and desire for the product, so the company will be chosen over the competition [20].

Based on the understanding in literature and the case "automated tissue engineering on demand" a target system can be derived consisting of strategic, technology and financial targets Figure 4. Strategic targets mainly include the dimension of protecting the already achieved competitive advantage and obtaining further competitive advantage by exploiting technologies comprehensively. Technology targets are derived from the strategic understanding of technology management, where technology timing and technology performance are two crucial factors to manage technologies. Finally, financial targets to maximize returns and minimize expanses are respected in the target system due to the fundamental business need to achieve monetary success.

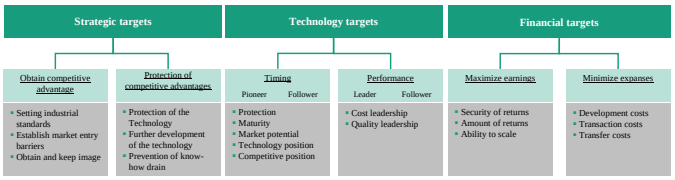

Figure 4. Target system for technology exploitation

Example Automated Tissue Engineering on Demand

The Fraunhofer research team (www.fraunhofer.com) applied this target system to commercialize the results of the project automated tissue engineering on demand. This target system formed the fundamental decision framework to evaluate different available exploitation options. In this case, the potential exploitation option should primary generate high monetary returns and enable further development of the technology. Considering the above mentioned target system, financial and strategic aspects of the target system were evaluated to be the most important for the project. In fact, the R&D costs of the production prototype exceeded several million Euros; a quick financial return had to be generated. In addition, the commercialization should still keep the opportunity to further establish the life science sector within Fraunhofer based on the developed technology. Beside this primary target, secondary targets were established to assure access to the developed know-how, guarantee flexibility and allow low expenditures to transfer the technology within the next two years. These different targets were weighted by the investors and resulted in a prioritized target system for the evaluation of the preferred exploitation option. First were financial targets, second were strategic targets and third were technology targets.

B. Options of exploitation

In the sub-model options of exploitation, the generally available internal and external exploitation options are

identified, structured and described with regard to their strength, weaknesses, opportunities and threats. This results in a fundamental description of characteristics of the available options for action. The internal technology exploitation refers to the use of existing technologies in their own products. At the same time, as part of the model of options of exploitation, it is necessary to consider if within the internal exploitation another distinction between different internal exploitation options has to be done. Although the division of the internal exploitation options does not seem useful at this time, considering all factors that contribute to different objectives, a differentiation in various geographic regions or business fields could lead to new internal exploitation as a result of the different characteristics. A further division of internal exploitation could entry the sub model of exploitation options, if the features of those options differ widely.

The external technology exploitation describes the commercialization of technologies outside the company. The literature shows different approaches that serve to structure the present paper (see Figure 5). However, most authors distinguish between joint-venture, licensing and selling the technology. Licensing and selling the technology represent independent exploitation options, which probably do not need to be divided any further. Yet the joint-venture is a group of exploitation options that could be divided again into joint-venture, strategic alliance, R&D cooperation and, if necessary, franchising. Furthermore, the option of no exploitation needs to be considered. Because of different criteria, for example timing or current technological capability, for strategic reasons it could be useful to take distance from exploitation of all kind and to decide about it at a later point under different conditions.

	Birkenmeier 2003	Granstrand 1999	Brodbeck 1999	Boyens 1998	Wolfrum 1994	Ford 1985/2001
Internal exploitation	Internal exploitation	Internal exploitation	Internal exploitation	Internal exploitation	Internal exploitation	Internal exploitation
Joint exploitation	Joint venture	Joint venture	Joint venture		Joint venture	Joint venture
	Strategic alliance	r&d cooperation	Strategic alliance		Strategic alliance	
					r&d cooperation	
Licensing	Licensing in other regions	Licensing	Licensing in other regions	Licensing	Licensing in other regions	Licensing
	Licensing in other industries		Licensing in other industries	Cross licensing	Licensing to competitors	Contract manufacturing
	Licensing to competitors		Licensing to competitors	Grant back Licensing	Licensing to suppliers	
	Licensing to suppliers		Licensing to suppliers			
Technology disposal	Patents sale	Technology sale	Patent sale	Patent sale	Technology sale	Technology sale
	Technology sale	Spin-out of innovative ventures	Technology sale			
	Spin-off	Split-off	Spin-off			
	Business area sale		Business area sale			

Figure 5. Overview of exploitation options

After the identification of the various internal and external exploitation options, they need to be analyzed fundamentally. A strength-weakness-opportunities-threats analysis can be performed to develop a profile of the individual options. This profile can be used in a further step to compare the target with the target system. In this process, the effect of the specific features of the exploitation options on the target need to be developed. This is how the use of exploitation options regarding to the target is characterized not including internal and external factors of influence. The results of the sub-model options of exploitation are various internal and external options of technology exploitation, which can be chosen to commercialize a technology. The specific features of the exploitation options are described to evaluate the effect of the different context factors. Moreover the contribution of the exploitation options to the different targets of the target system is characterized. The results of the sub-model serve as a quantity input for the model for selecting the exploitation options and, in context of a decisive theoretical approach; they also represent alternatives for making a selection.

Example Automated Tissue Engineering on Demand

To decide which exploitation option should be utilized for producing skin models automatically, the following possibilities were considered: internal exploitation, R&D cooperation, licensing, joint-venture, spin-off and purchasing of the technology. In the course of the different options, their fundamental strengths and weaknesses regarding the objectives were described and certain characteristics of the technology, the market and the company were ignored.

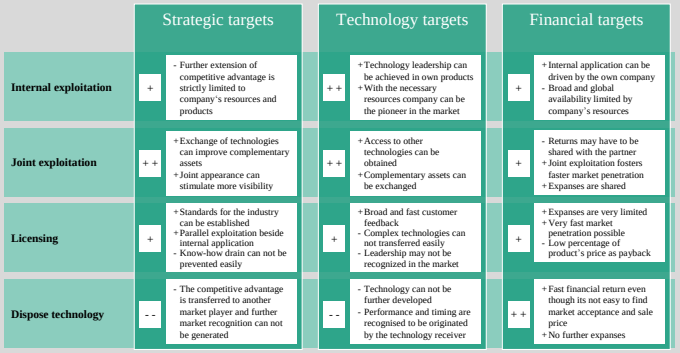

Figure 6. Interdependence target system and exploitation options

C. *The technology model*

The aim of the technology model is to identify and describe the essential influencing technical factors that lead to a differentiated evaluation in the decision situation. Therefore, the various features as well as their characteristics from related literature are collected and structured (see Figure 7). In his book, Wolfrum pictures the technological performance, the timing of innovation and the technological source as the main influencing variables [21]. Escher, Ford and Ryan mention furthermore the way how a technology is protected and subsequently how exclusively the technology is [42]. They also describe the entire patent strategy as a feature to choose an exploitation option [1, 51]. In his dissertation, Birkenmeier emphasizes the competitive position of the technology as another characteristic that should be included in the decision making process [16]. It remains unconsidered that this feature only can be described in addition to the market to be addressed. Therefore, Birkenmeier arranges the technologies into fundamental, key and pace maker technologies even though the literature still discusses critically the S-curve concept [52]. Furthermore, Birkenmeier refers to the functional relevance of a technology as another technological feature in the task of exploitation and therefore distinguishes the technologies into core and support technologies [16]. Mittag, Tschirky, Ford and Ryan recommend the stage of technology life cycle, in which the exploited technology is the most important variable [27, 5,

19]. Lichtenthaler emphasizes this aspect and also demands the consideration of the technology potential in further research, which has a close connection to the available technology life cycles [53]. The result of the technology model is the characterisation of the technology, which will be used as an input in the selection model of the exploitation options.

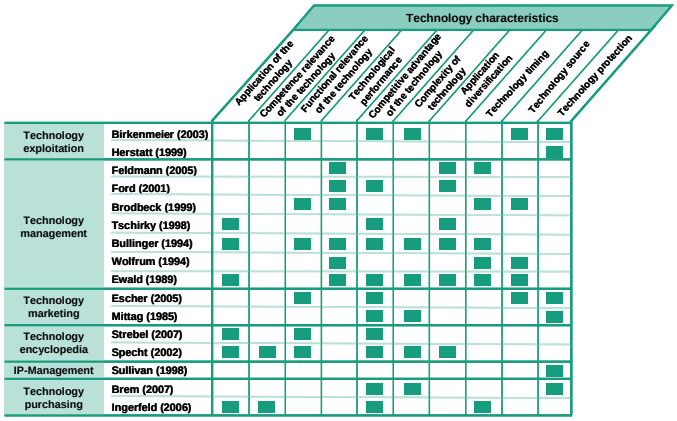

Figure 7. Characteristics of technology in literature

Example Automated Tissue Engineering on Demand

The technology developed by Fraunhofer is globally unique. It represents a pacemaker technology and supports the strategy of technology leadership. The production technology was developed internally and has a high advancement potential, though being currently still in the development stage. The transferability is only given with significant human resources, because of the prototypical expenditure and the implicit knowledge of the developing engineers. Keeping that in mind, the characteristics of licensing and selling the technology get a rather low assessment, since transferring the knowledge to a potential customer means also to transfer an enormous number of human resources from Fraunhofer. Furthermore, discussions with potential cooperation partners show especially that the capital intensive goods are reluctantly sold or licensed in an early stage, because of the lack of confidence in the technology within the market. The uniqueness of the technology exacerbates the market acceptance as there is no application experience. Regarding the shown characteristics of technologies R&D cooperation, joint-ventures or spin-offs are better assessed than licensing or selling the technology.

D. The market model

The market model includes two major steps. First, the addressed market where the specific technology should be exploited is defined. Second, the defined market is specified by the relevant market characteristics to exploit the contemplated technology. The clearly delimited market is subsequently characterised by the means of the available market mechanisms. In the course of that, various market information arise, which are relevant to evaluate the exploitation options within the selection model.

Starting with demarcation of the contemplating market, the market based observation area is determined by the used technology. The aim is to define a market where the exploitation objects are commercialised. The determination of the market is methodically supported by the approach at hand. Therefore, a process has to be developed, in which the user is allowed to demarcate with different criteria his market based observation area. As soon as the market based observation area is delimited, it needs to be characterised with suitable features. Thus, there are countless suggestions about how to characterise a market in literature. A concrete approach to characterise markets is provided by Porter with the five competitive forces [54]. According to that, a certain market can be described through the immediate competitors, the potential competitors, the customers, the suppliers and the substitutes. As a part of his dissertation Birkenmeier recommends certain features that could be used in the exploitation situation [16]. For this purpose, he lists task oriented features like technology or innovation intensity as well as general factors like technological, economic, social and ecological conditions, which are mostly mentioned also by other authors [5, 16, 1]. Arora adds the extent of the division of labour within the viewed market to the deliberations, as from his point of view it is a calculation basis for the willingness to exchange technologies [6]. The result of the market model is a characterised market on which the exploitation object can be commercialised. The information about the market is needed essentially to make a decision within the selection model, since the exploitation options depend significantly on the attractiveness of the viewed market. Therefore, the market model forms are an important input quantity for the selection of an exploitation option.

Example Automated Tissue Engineering on Demand

The production plant of the Fraunhofer Foundation is able to produce human skin models in significant quantities (5.000 pieces a month, 1cm diameter). These skin models can be used instead of animal and human experiments for safety and efficacy tests in pharmaceutical sectors, cosmetics, chemical or medical sectors, as well as to release new products and substances on the market. The main focus was determined on utilizing the technology in Europe. An annual market volume of approximately 100bn Euro was estimated and could be achieved within the next five years (increase of 20% a year). The market is dominated by a few test system manufactures (Skin Ethic, Cell Systems, Epithelix, Sterlap, Phenion). Due to the characteristics of the market and the lack of financial resources of the market participants, selling the technology was immediately excluded from the decision making. Licensing the technology to a customer was neither an option, since the maturity of the technology is not ready for a low failure mass production (standardized high quality production) nor the acceptance of the market is still missing. A joint-venture or spin-off which only uses a few plants to produce and to distribute skin models appeared to be the most reasonable option to utilize the technology in a reasonable time and with appropriate resources. Internal human resources of Fraunhofer could be transferred in such a spin-off or joint-venture to improve the maturity of the technology and start getting first market acceptance by selling the tissues at the same time.

E. *The company's model*

The company's model describes the business based features and characteristics that are relevant to the evaluation of the various exploitation options. The information about the influencing characteristics of the company was adopted in the selection model. There are various approaches in literature that explain how to characterise a company. However, the issue is also to discover how the influencing factors have an impact on the exploitation decision. The literature concerning exploitation delivers first answers. Birkenmeier and Escher argue that strategic and resource induced operations are relevant features to describe a company [16, 1]. Therefore, Birkenmeier and Escher emphasize the impact of patent strategies as well as procurement strategies on the exploitation decision [16],[1]. The resource induced elements describe the available potential of innovation and marketing in the company [16],[1]. The authors indicate the relevance of financial, personnel and temporal capabilities of the company and the available knowledge regarding the exploitation activities [55, 56]. In the present paper, the internal technology exploitation is confronted with the external, which means some descriptive elements that allow a differentiation must be mentioned. The internal exploitation is easier to pursue by using an existing production in a chosen geographical area than utilizing a missing structure of production in the elected area. The task of the company's model is to identify the basic features to describe the company and to check their relevance. As a result, a characterisation of the company on the viewed market is accomplished, which can be used in the decisive situation and therefore as an input of quality in the selection model.

Example Automated Tissue Engineering on Demand

With its 18.000 employees and an annual research budget of approximately 1,66bn Euro, the Fraunhofer Foundation is the largest organisation for applied research and development in Europe. Being funded internationally, the Fraunhofer Foundation promotes application oriented research, which benefits both the economy and the society. Due to the Fraunhofer articles of association, it wouldn't be possible to produce and sale the skin models in large scale within the Fraunhofer Foundation. Subsequently, only external exploitation options such as spin-off, joint-venture, R&D cooperation, strategic alliance were considered in the decision situation. In conjunction with the characteristics of the technology (high expenditure to transfer technologies, young technology with only little market acceptance), the joint-venture and the spin-off were estimated as the exploitation option with the highest benefit for the Fraunhofer Foundation.

F. *The selection model*

Through the selection model is made an evaluation of the various available exploitation options. This model adjusts to the customized target system, it takes into account not only the influence that the technology's characteristics exert on the selection model, but also the effect on it of the market specific features and the characteristics of the exploiting company.

The selection model forms the core method of evaluation and selection. The specified features of the above mentioned description models concerning the technology, the market, the target system and the exploitation options are interdependent, which characterises the exploitation situation that must be evaluated. The exploitation model has to process the input information – also considering the efforts on evaluating and characterising the situation in question – in order to get to a reasonable evaluation. The theoretical basis for assessing and selecting a suitable evaluation model comes from decision theory. In order to enable a holistic evaluation of the various available exploitation options, there must be an evaluation of the influence of market, company and technology characteristics on the contribution of the exploitation options to the objectives of the target system. This contribution, which is characterised by the features of the different exploitation options in conjunction with the objectives of the target systems, can be increased or decreased by the internal and external influencing factors. For this reason, the analytical hierarchy process (AHP) is proposed to be used as decision making method.

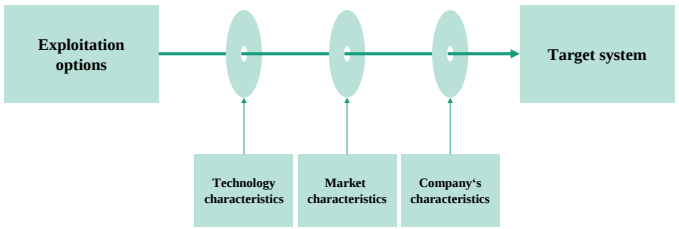

Figure 8. Decision making methodology

Example Automated Tissue Engineering on Demand

The Fraunhofer team assessed the degree of fulfilment of the different exploitation options based on the defined target system. The highest possible monetary return would be achieved through licensing, since thereby the entire market could be handled. The internal exploitation would mean the lowest expenditure, yet that was not an option because of the articles of association of the Fraunhofer Foundation. The establishment of joint-venture or R&D cooperation had the highest potential to advance. The access to the technology would be mostly guaranteed through internal exploitation and licensing, whereas licensing holds the danger that the developed knowledge gets lost in the medium to long term perspective. Because of the low market acceptance and the young technology, a spin-off emerged to be the exploitation option that would provide the biggest flexibility and would also be realizable in the shortest amount of time. That is why the spin-off has been identified as the preferred exploitation option to utilize a production plant that is able to produce skin models.

V. CONCLUSION AND FURTHER RESEARCH

Nowadays, increasing technology investments have to be amortized in a shorter amount of time, since the lifecycles of technologies and products are decreasing considerably. Therefore, the pressure on the companies to leverage, at an early stage, a maximum of the technological commercialisation potential is also increasing. However, there is both in the practical industrial field and in the current state of the art of research a lack of strategy to support exploitation decisions. With regard to this situation, the objective of the present paper

was to discuss a first approach for a decision making model that enables the selection, amongst the various possibilities, of a qualified exploitation option that also considers the essential internal and external influencing factors. On the basis of the current state of the art of research and the experiences with commercialising technologies made at the Fraunhofer IPT, the different influencing factors on the exploitation decision were investigated and, afterwards, transferred into an all-embracing approach. The user specific targets, the typical characteristics of the company, the market and the technology were all contextualized.

The compiled approach serves as a first framework for further research. Therefore, each sub model needs to be detailed. The interdependencies of the sub model characteristics on the various exploitation options needs to be described and adopted into the evaluation model. In addition, the suggested interdependencies can be evaluated by an empirical research. Finally, the analytic hierarchy process needs to adopt all the evaluations and support further decision making processes in the industry. After having detailed the exploitation decision model, approaches for supporting the actual technology transfer between different organisations should be analysed. In the past years, modern web technologies and social software opened up new possibilities to support the inter-organisational technology transfer via web-based transfer platforms. These depict a promising approach which should be further investigated in the future.

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