IOSR Journal of Business and Management (IOSR-JBM)
e-ISSN: 2278-487X, p-ISSN: 2319-7668. Volume 18, Issue 11. Ver. VII (November. 2016), PP 90-103
www.iosrjournals.org

Technology capability: Identification and assessment of technology and market specific exploitation options

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Abstract: *Diminishing product and technology lifecycles are compelling companies to exploit their technology potential to the full and pursue an appropriate technology exploitation strategy in order to thrive in the current environment. The aim of this paper is to extend the existing decision model for technology exploitation, which takes all relevant factors of the commercialization situation into account. In particular it focuses on the diversification potential of a technology, on how to generate new areas of application out of it and to evaluate these in terms of their market potential. This will give companies an opportunity to evaluate different exploitation options in the context of company-specific objectives and situation-specific factors in order to derive a suitable exploitation option. The model is validated on the basis of a case study conducted by the Fraunhofer Institute for Production Technology.*
Keywords: *technology based diversification, market assessment, technology exploitation, exploitation options, technology commercialization*

I. Introduction

1.1 Occurring challenges and unused technology potential

Products are brought to market in ever shorter cycles. To be able to compete on the market, companies need to constantly introduce new and innovative technologies.

Many of the products currently on the market are produced using a bundle of different technologies, making it impossible for manufacturing companies to develop each technology by themselves [1]. In addition, the demand for foreign technologies can be explained by an industrial shift from a high to a low level of vertical manufacturing companies, whereby, less relevant technologies are no longer developed or applied in-house but are instead, externally sourced.

The mounting complexity of technologies and the rising factor costs have led to a continuous increase in development expenditure [2, 3]. Due to globalization and increasing competition, companies are also forced to bring new innovations to market at ever shorter intervals [4]. The shortened product life cycles have in turn resulted in a reduction in the useful life time of the technologies used in the product which gives companies less time to recover their R&D costs and to earn profit [5]. Companies are thus increasingly faced with the problem that exclusive utilization of their technology in their own product is no longer sufficient to cover all costs [6]. As a result, companies try to optimize their technology potential by pursuing alternative exploitation strategies, thereby ensuring maximum profit and strategic success.

It makes economic sense not to limit the use of a given technology to only one industry. Cross-industry exploitation offers considerable potential. By identifying the potential for using its own technology in foreign markets, companies can expand their own areas of business. Radical innovations frequently stem from this process [5]. One example of successful cross-industry collaboration is the BMW iDrive technology, which gives the driver intuitive and interactive control of the board computer via a button. The technology for this was provided by a young high-tech enterprise, which had nothing to do with the automotive industry, but specialized in joysticks for medical technology [7]. Through the use of external knowledge, BMW succeeded in developing iDrive within 2 years for series production, which is much shorter than the usual development phase.

Apart from the commercialized technologies, there is also an immense volume of technologies that are not used because of their lack of strategic fit to the company [8]. However, it is this technological knowledge in particular, which provides enormous potential to increase sales via external commercialization ([3], [9], [10]).

1.2 Gaps in current research

Schuh and Drescher identified the need for a useful decision method to support the complex exploitation question, taking account of internal and external factors [11]. They introduced a technology exploitation model including all relevant factors for a situation specific exploitation decision. Until that point, there had been scant discussion of technology exploitation in the literature. In particular, the complex decision-making process relating to the issue of exploitation, taking account of internal and external factors, was given only minimal consideration ([1], [3]). The existing approaches did not acknowledge factors such as technology, market and company characteristics sufficiently.

However the model focuses only on the exploitation of an existing technology in one defined application. Nowadays it is essential to diversify the existing technology for application in different markets and products in order to reveal the full potential of a technology. As demonstrated, cross-sectoral exploitation offers immense potential for companies to increase their profitability.

1.3 Aim and research methodology

The model of technology exploitation for systematic leverage of technological assets developed by Schuh and Drescher provides the basis for this paper [11]. The model with all the sub-models was already in place. This paper outlines the further development of the model and presents a methodology, with which the exploitation options can be selected taking account of the technology-specific market potential. Companies are given the opportunity to evaluate different exploitation options in the context of company-specific objectives and situation-specific factors in order to derive a suitable exploitation option. Attention is focused particularly on the diversification potential of a technology. It is important to realize the potential of a technology in order to generate new areas of application and to evaluate them in terms of their market potential.

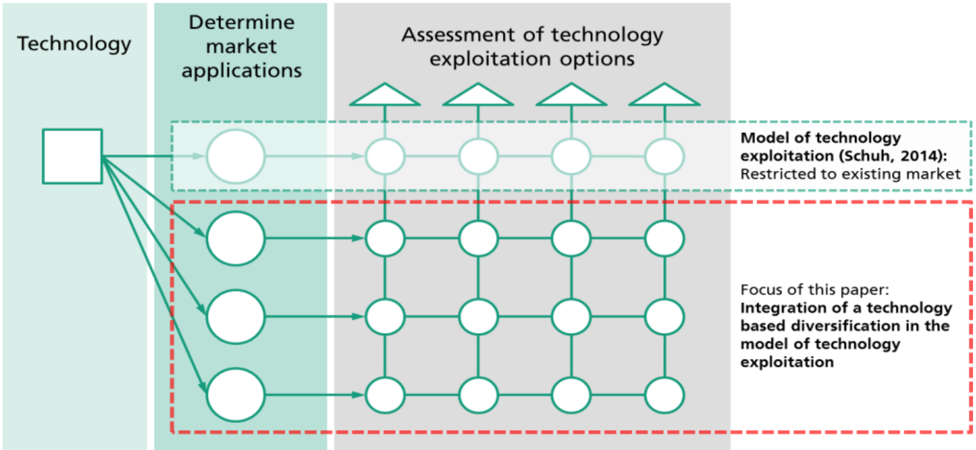

Fig. 1: Focus of the Paper

1.4 Research Methodology

The Fraunhofer-Gesellschaft can draw on many years of experience in technology exploitation through various industrial projects as well as in frequently organized European wide benchmarking in technology management. Using this know-how as the basis and including an intensive examination of the latest literature the decision model was developed. It includes existing exploitation options and a company-specific target system. The market and technology factors affecting the decision are also considered. The model was subsequently evaluated in the course of several case studies conducted by the Fraunhofer Institute for Production Technology IPT and was piloted in the example of Tissue Engineering by Schuh and Drescher [11].

Introductory Case Study

The developed methodology is validated via a case study based on the technology of the on-going "Automated Tissue Engineering on Demand" research and development project undertaken by the Fraunhofer-Gesellschaft (FhG). This interdisciplinary Fraunhofer project deals with the problem of developing a manufacturing system for the automated production of human skin. Fraunhofer has managed to transform manual labor and labor-intensive skin production into an automatic, industrially applicable manufacturing process. This has resulted in the development of the "Tissue Factory", a sterile production plant with a monthly capacity of 5,000 human skins. Industrial production of artificial skin is motivated by demands for the abolition of animal experiments which has led to an increase of in-vitro test systems [12].

Schuh and Drescher already highlighted the exploitation process within their model by focusing on the exploitation of the technology in its original planned application, the "Tissue Factory" [11].

However through the established process and the existing know-how, it is conceivable that the production system is not limited to the current application, but has the potential to open up new markets. Applying the methodology developed in this paper, the technology of "Automated Tissue Engineering on Demand" is now used to identify and assess new market potentials and new applications. The model of technology exploitation is subsequently used to evaluate these new applications in terms of different exploitation options.

II. The model of technology exploitation

The aim of the technology exploitation model is to support the decision maker in selecting a suitable exploitation option using a decision-making tool. It is, therefore, vital that all factors influencing the decision situation are taken into account to permit situation-specific assessment of the exploitation option.

For the exploitation model we identified four main factors. The key factor for the exploitation situation is the diverse range of exploitation options. It is also essential to develop a target system customized to meet the needs of the company. Additionally the technology and the market must be factored in.

These sub-models of the technology exploitation model interact with each other. Alongside the influence they exert individually on the decision situation, their interdependencies must be taken into account so that a non-specific situational assessment is possible.

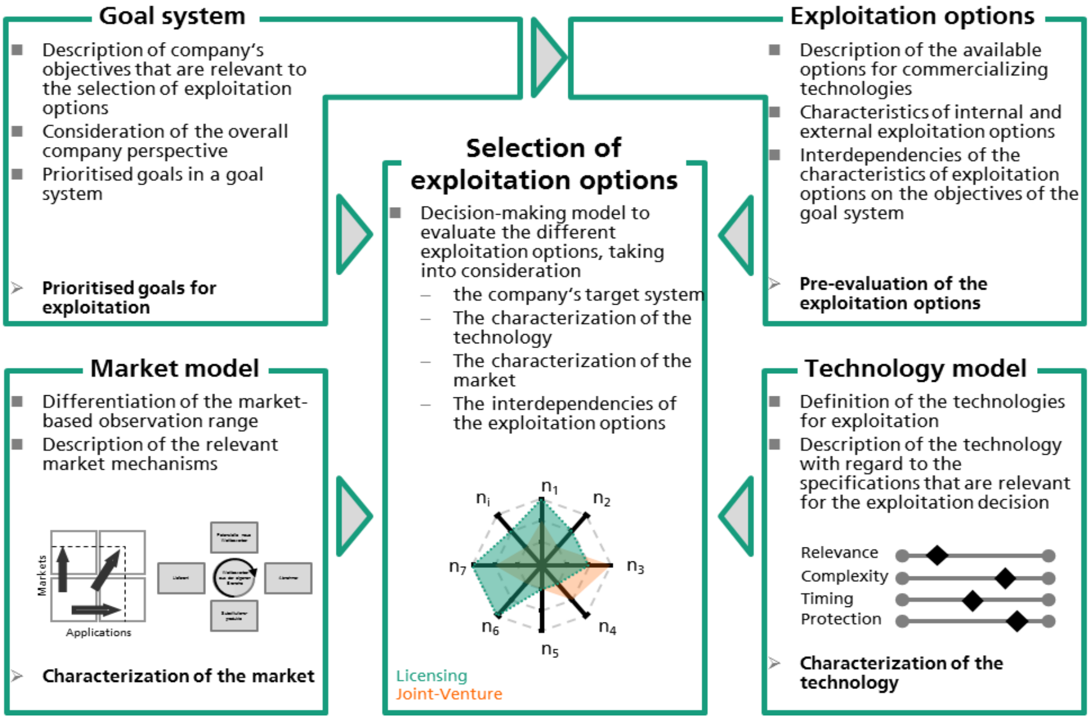

Fig. 2: Model of technology exploitation [11]

2.1 Exploitation options

A distinction can be drawn between internal and external exploitation options (see Fig. 3). In internal exploitation a company uses the technology in its own products and processes; in external exploitation the distinctions relate to licensing, technology disposal or joint technology utilization by cooperating companies [13]. Each of these exploitation options is influenced by their own motivation and characteristics [14].

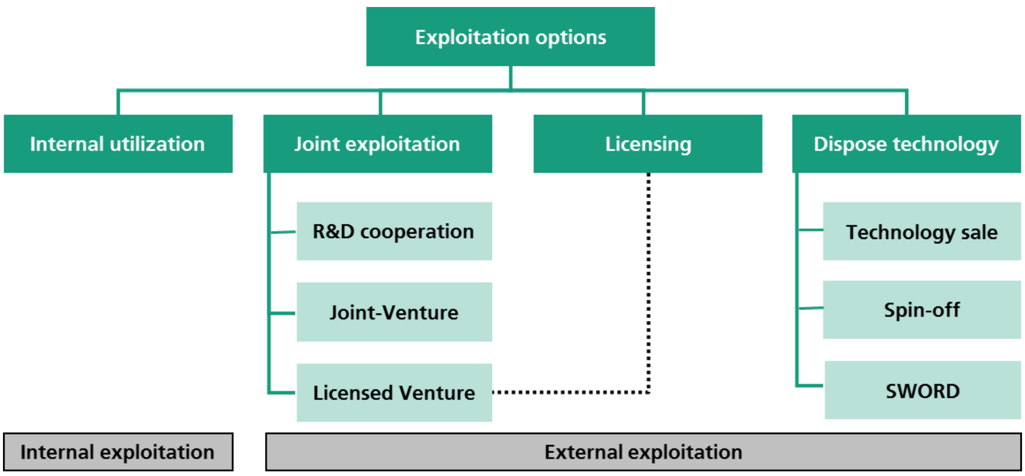

Fig. 3: Possible exploitation options

Internal exploitation

If technologies are used in the processes or products of the company which developed them, utilization is described as internal [15]. The company objectives in the context of internal exploitation technology are to generate a competitive advantage as well as to satisfy customer requirements by providing its own products and processes [13].

Licensing

Licenses are used to transfer the legal authority for the commercial use of a technology in return for a compensation payment from one company to another [14]. In this type of external technology exploitation, the property rights remain with the licensor.

Joint exploitation

R&D co-operation is often entered into if in-house development of a technology is too time-consuming and community research promises much faster results [16]. A bilateral, complementary exchange of knowledge, skills and technological resources, which generates synergies, takes place ([16], [17]). Joint venture is an intensive form of cooperation partners' agreement. Through the creation of a holding company by several independent companies a new, legally autonomous venture is founded [18]. The licensed venture is a hybrid between a spin-off of a new holding company and licensing and was created by the FhG, whereby the licensed venture does not own any rights to access the technological knowledge, but it is transferred in the form of a license to the licensed venture [19].

Dispose of technology

During a technology sale a legally binding ownership transfer of the technology from seller to buyer takes place. Therefore, the buyer acquires the exclusive rights to use and exploit the transferred technological know-how as well as the underlying property rights [20]. If technologies, product ideas, products or employees of an existing company as well as the associated rights and relevant patents are transferred to a newly formed subsidiary company, it is called a spin-off ([20], [21], [22]). The Stock Warrant off-balance-sheet research and development (SWORD) offers the possibility to outsource individual technology projects in separate organizational units and to finance them via the capital market [23]. It is contract research for investor groups initiated by the technology owner in which both sides own purchase options.

2.2 Goal system

The basis for rational decision-making is always a group of defined objectives that a decision maker is trying to achieve by selecting the most appropriate option from those available. The objectives of technology exploitation are identical to strategic goals of the company. During this process, companies often seek to achieve multiple targets simultaneously [24]. Multiple company goals in one technology exploitation situation were analyzed in the course of a number of steps and subsequently reviewed in terms of their redundancy. This formed the basis for the development of a special target system for technology exploitation in which we identified four redundancy-free main targets. These can be grouped into strategic and financial goals, as shown in Fig. 4.

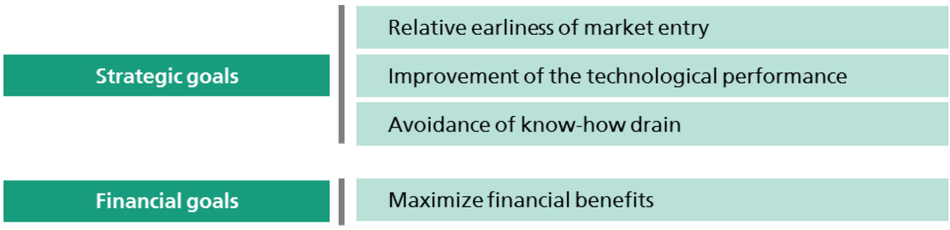

Fig. 4: Goal system of the exploitation model

Strategic goals

To improve the position of a company within the existing market, it is necessary to hone specific competitive advantages [2]. Competitive strategies support the build-up of long-term competitive advantage over competitors [3]. This aspect can be further promoted with the help of external technology exploitation [25].

The timeliness of the market entry point, at which innovative technologies are brought to market, is significant in terms of the competitive strategy ([20], [26]). Depending on the target characteristics, a company can choose whether it will pursue a pioneer or a follower strategy and thus achieve competitive advantages by being ahead of time or accept the delay until technology commercialization [27]. The relative technological performance is defined in literature as a development lead or lag vis-à-vis the current state of the art or the competitors ([13], [14]). Companies which perform more efficiently than others can achieve technological leadership, whereas companies that neglect their technological potential just take a presence position [28]. Advantages over competitors must be protected to consolidate a company´s market position and hence continuously generate above-average profits. Different availability of competition-relevant resources is seen as the basis for competitive advantage [25]. It is important to conserve these resources and to protect them from know-how drain.

Financial goals

The financial goal of an enterprise in the context of an exploitation decision is only influenced by the financial benefit that an exploitation option can provide. Therefore, the aim of maximizing the financial benefit to evaluate the optimum exploitation alternative is included in the exploitation model. The financial benefit is a calculative, quantitative value, which is determined by taking account of risk preferences, expected value and value scattering.

2.3 Technology model

Exploitation decisions are influenced mainly by the existing technologies and their characteristics. We identified a range of technology characteristics in the existing literature and analyzed these in terms of their impact on the exploitation decision. Characteristics which are redundant, already included in the goal system or which do not influence the exploitation situation were excluded from the technology model (see Fig. 5).

Characteristics	Specification		
Competitive relevance	Pacemaker technology	Key technology	Basic technology
Functional relevance	Core technology	Support technology	Irrelevant technology
Technology complexity	Simple technology		Complex technology
Technology protection	IP protection		No IP protection

Fig. 5: Technology influence of the exploitation model

Competitive relevance

Competitive relevance is particularly significant for the competitive position of a company and the generation of competitive advantages. Technologies can be divided into three phases through the technology S-Curve ([2], [29], [30]).

Pacemaker technologies are technologies that are at the development stage and are based on specific, not yet generally available knowledge [31]. Key technologies are at the growth stage and are already being used in specific applications and processes. These technologies are characterized by high performance potential and thus are of high strategic importance for the companies [32]. Technologies which are in the maturity phase are referred to as basic technologies. Their technological performance limit is almost reached, the range of applications is known and as a result of their longstanding involvement in the market, have been mastered by a large proportion of the company´s competitors ([16], [33]).

Functional relevance

The strategic importance of the technology can be highlighted by categorizing a technology in the company value chain,

Technologies of high strategic importance to the company are referred to as core technologies. These technologies are usually characterized by unique features and make a significant contribution to the success of the company ([2], [34], [35]). Support technologies prop up the competitiveness of core products and processes by providing secondary and auxiliary functions; however on their own, these technologies are of limited use. Functionally irrelevant technologies are not relevant to internal utilization due to the strategic focus of the company.

Technology complexity

The complexity of a technology is of immense importance for technology transfer [36]. Simple technologies consist of only a small amount of information and as so called explicit knowledge, they are easy to document. The transfer of these technologies is simple and cost-efficient. Complex technologies possess a high level of information, are linked and may therefore require considerable effort [30].

Technology protection

Once technological knowledge is available, it can be used at any time due to its status as public good [36]. Organizations can only achieve a competitive advantage with increased income, if the technological know-how is withheld from the competition [37]. Know-how can be protected by governmental property rights. These rights are used to prevent imitations and unwanted development by third parties. Otherwise these rights can be used to prevent the acquisition of property rights by competitors, which could restrict the scope of action of the company which developed the technology [38]. Know-how without property rights is a serious problem for external exploitation, as there is no legal way of preventing abuse and opportunistic behavior [13].

2.4 Market model

Since the success of a technology always depends on the presence of demand, it is vital to take market factors seriously when evaluating an exploitation decision.

Markets differ from one another because of their specific characteristics. A phase model can be used to segment the technology market. This may involve delimitation of geographical areas, individual industries, company size, performance parameters or risk behavior.

A distinction can be drawn between the macro and the micro economic environment in order to generate significant market-specific information about the more restricted business environment ([39], [40]). Macro-environment is defined by socio-cultural, economic, political-legal and technological factors as well as physical and environmental aspects. On the other hand micro-environment covers competitors, customers, suppliers and substitution technologies ([40], [41]).

Nowadays, the demand for products and associated technologies is characterized by high fluctuation. In order to predict future developments and thus minimize deviations from projected values, it is essential to foresee market developments. In terms of the technology exploitation market, a forecasting strategy which considers quantitative, business and multi-causal factors for the period of exploitation is useful. In principle, forecasting methods for future sales can be divided into systematic and intuitive methods ([39], [41]).

Like products and markets, technologies are characterized by life cycle concepts in which the dependency of the technology age on an external factor such as the achievable profit, competition potential or sales volume is observed. For the technology life cycle (TLC), there are three well-known concepts which are explored by Arthur D. Little, Ford&Ryan and McKinsey´s S-curve [42]. The TLC states how close to market a technology is and hence can be used for pricing.

Essential key indicators are always influenced by future, unforeseen environmental events. To counteract the chance factor, different probabilities are used in practice. The scenario technique is a plan of action which permits scenarios along with future developments and changes to be recorded. Application of the decision tree method is useful in order to demonstrate effects of deviations of individual factors on the overall result; it is particularly well-suited to taking account of future potential decisions.

2.5 Assessment of the exploitation situation

An Excel-tool based on the assumptions of the analytical hierarchy process (AHP) was developed for situation-specific assessment. The tool enables conclusions relating to complex circumstances to be drawn and generates a solution through mathematical calculation. The calculation is based on comparison of the exploitation options in pairs and assessment of their adequacy on a scale from 1/9 to 9. A ranking is drawn up reflecting the degree to which each of the exploitation options meets each target. The consistency check subsequently implemented, results in direct validation of the input values. In assessing the exploitation alternatives in financial terms, the target is based solely on calculating financial benefits. In particular, the net present value is influenced by the prevailing technology and market characteristics. All relevant technology and market indicators as well as financial characteristics of each exploitation alternative can be taken into account. In addition, the situation-dependent business goals can be weighted via the pairwise comparison involved in the AHP. A ranking of the situation-specific, optimal exploitation alternative is displayed following a full declaration of all relevant data.

Thus the Excel-tool captures the complex interdependencies of the exploitation decision and determines a meaningful recommendation for action in response to the exploitation problem.

III. Technology based diversification

So far the model of exploitation is configured only for using a technology in one single application. However technology based diversification helps to extend the technology to cover different markets and to obtain the maximum profit out of a technology.

Based on the approach developed by Bullinger [43] we demonstrate how several new potential markets can be identified for an existing technology and how these can be analyzed in detail in relation to the exploitation decision. The following 5 steps outline the approach which is validated by the case study:

1. Identifying technology potential
2. Technology competitive analysis
3. Identifying potential applications and market analysis
4. Collating all applications
5. Selection and evaluation of the applications

3.1 Identifying technology potential

Technologies involve very complex relationships between various factors and capabilities. Therefore, it is necessary to come to a precise understanding of the structure and the performance of an existing technology [43]. The aim of the search for new market opportunities is to identify analogies between the existing technology and potential fields of application [7]. To identify new sales markets totally detached from current technology fields, the technology must be abstracted to a general description [44]. This procedure is based on the TRIZ logic created by Altschuller. We identified two approaches to generate an abstract description for a specific technology.

Functional Analysis

Using Bullingers approach of a functional analysis, a comprehensive technology profile is created and an interface between potential sales markets and the existing technology is established on this basis. The functions and attributes of any given technology serve to connect these two entities. A link is thereby established between possible market requirements of potential sales markets and the respective functions of a technology [45].

Abstraction Tree

Echterhoff uses the abstraction tree approach, which is divided into two parts [44]. The upper part contains the concrete problem whilst in the lower part the problem is described in abstract terms. A distinction is made between problem elements, system elements and target elements. Problem elements define characteristics of the specific problem, system elements describe physical components that interact with each other and target elements show the result to be achieved.

Functional analysis for the case study

The fully automated production process of the tissue factory was fragmented into its individual components, functions and attributes using functional analysis. The Tissue Factory was found to comprise three individual modules, each of which exerts a different influence on the production process. This approach yielded a better and clearer understanding of the technology and is shown in Fig. 6.

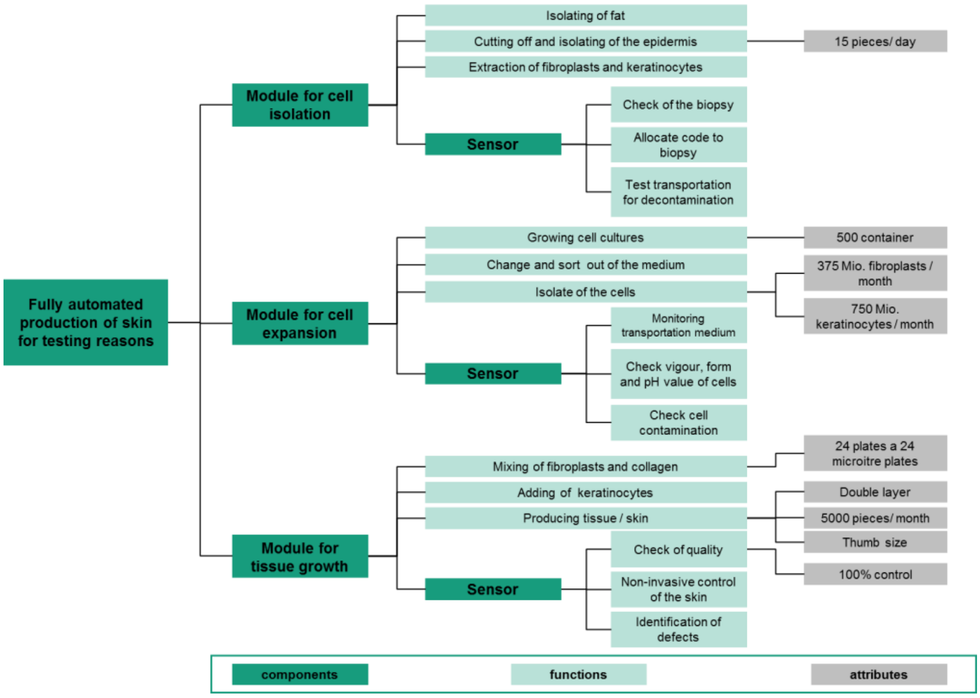

Fig. 6: Functional analysis of the case study

3.2 Technology competitive analysis

To generate a general overview of the existing technology environment, it is vital to analyze the competition. A structured competitive situation can be developed on the basis of the abstraction level. Besides the state of the art, future development opportunities and new technologies should also be considered. A competitive analysis must be performed inside and outside the original technology market.

Internal technology competition is referred to as direct competition. Direct competitors own a similar technology and therefore address the same market as the technology owners. In contrast to this, external technology competition is referred to as indirect competition. This includes all technologies with the same functional profile as the existing technology or those which cover parts of the functions through intersections [45].

Competitive analysis for the case study

Based on the functional analysis a technology competition analysis was performed in order to illustrate the competitive situation within tissue engineering. The automated production of skin models is a completely new process; so far there are no direct competitors. In this case, the only entities which could be regarded as direct competitors are special laboratories which grow skin models in labor-intensive manual work. Animal experiments represent external technology competition, which addresses the same market as the Tissue Factory.

3.3 Identifying potential applications and market analysis

In the next step concrete potential applications and future sales markets for the existing technology are identified. It is anticipated that this will be achieved through a structured process incorporating both the current state and future developments. Bullinger demonstrates means of intensifying the search for new sales markets using different systematically structured methods [44]. A wise mix of strictly systematic and creative approaches is considered useful [46].

Existing applications

Internal and external competitors have already been identified via the technology function profile. The product portfolio of these competitors can now be used to derive potential areas of application for the existing technology.

Creativity techniques

Creativity is an important and essential aspect that should not be neglected. A concentration of expertise in teams and the implementation of creativity workshops for the identification, analysis and evaluation of potential applications can lead to very good results. In particular, care should be taken to ensure that the workshop participants have a diverse range of skills and requirements.

Patent databases

Another way to identify new markets is to use patent databases. In addition to the actual information as to which technologies are protected by whom and to what extent, these databases also provide a source of information in which industrial areas, the respective technologies and functions are utilized. Therefore, a comprehensive patent database analysis can help to discover new, as yet unrecognized applications for existing technologies.

Text-Mining-Programs

The opportunities afforded by digitalization have made it easy to obtain reliable data swiftly. The main challenge is the analysis of the huge variety and quantity of available information ([43], [47]). However, since the human ability to absorb and process information cannot be significantly increased, the improvement is more likely to lie in better and faster methods of searching for and analyzing relevant documents [43]. Content analysis of documents calls for the application of text-mining methods; the information extraction method has a number of advantages in this context. This permits a large volume of documents to be analyzed and relevant content to be presented in various forms. When the system is configured efficiently, the time savings and improved quality of the results can be enormous.

The potential new areas of application for the existing technology must be analyzed in terms of their market potential. The relevant market fundamentals previously presented in the exploitation model are now used to assess the different applications.

Identifying potential applications and market evaluation in the case study

The different ways to identify potential markets described in the previous section are now applied to the case study of tissue engineering.

Pre-existing applications which may be of interest in relation to tissue engineering technology can be revealed via the competitors previously identified. The application area "growth of human tissue" was identified following analysis of the range of products of current medical laboratories or researches. This includes simple structure like cartilage and bones as well as complex human tissue such as trachea or esophagus [48]. In addition, a lot of research is currently being conducted into the development of stem cells to treat a wide range of different diseases. Stem cells are also used to grow tissue cultures. As the use of embryonic stem cells is banned in Germany, research is based on induced pluripotent stem cells (iPs). If these stem cells could be integrated within the automated production process, the potential this would generate would be enormous.

Where animal experiments are classified as indirect competition, other areas of application can be identified. In addition to the testing of toxicological skin compatibility of pharmaceutical, cosmetic or medical products, the use of animal organs for drug compatibility testing is a major factor in the medical sector. Automated growing of organs could replace around 380,000 animal tests in Germany alone [49]. A further development of this approach could even lead to the production of human organs for transplantation. Around 12,000 people are currently on the waiting list for donor organs in Germany. However due to the complex construction and extremely small vascular systems, a considerable amount of research is needed in this field.

Discussions within an expert group led to a utilization of large full-thickness skin models in transplantation medicine. Patients with burn injuries often need a transplantation of a large-area of real skin. The areas of skin need to be larger than those produced by the tissue factory and the skin requires blood vessels. In Germany around 110,000 skin grafts are needed annually [50].

A keyword analysis was carried out in the DEPATIS net patent database of the German Patent and Trademark Office using different word combinations arising from the functional analysis. This revealed the patents "Industrial production of meat from in vitro cell cultures" and "Producing animal leather skin substitutes patents, entails carrying out animal in-vitro growing of epithelial cells; laminating cultivated partly active cells on sterilized substrate and cultivating the cells in translucent incubator systems" ([51, [52]). At first glance, these applications seem unconnected to the technology of tissue engineering. However if it were possible to further develop the technology and integrate these applications into a fully automated production process it would lead to a high market potential. As a result the potential application fields of mechanical cultivation of meat as well as leather skin from animal cell cultures are identified.

3.4 Collating all applications

The potential applications collated, are now clearly represented and analyzed in terms of their potential for the exploitation decision. Different approaches are discussed in literature. Exploring the functional market concept to identify the most appropriate future applications, Pfeiffer conducts an analysis according to the criteria of technology attractiveness and resource strength of the company [53]. Another approach is provided by Echterhoff trying to estimate the adaptation capability of the technologies using a matrix [43]. Bullinger transfers the identified applications to an application list and examines these in terms of technological, market and competition-relevant criteria. A color scale can be used to assess factors which make it possible to identify swiftly which markets can be addressed at what time and to what extent. The concept developed by Bullinger is used in the model of technology exploitation.

In order to maintain consistency with the already known model of technology exploitation, we use the classification criteria technology and markets to analyze the applications identified. Technology criteria in this context are the identified functions and attributes of the technology but not the characteristics from the technology model. Applications with identical development potentials can thereby be identified and combined. Thus, synergy effects can be created and a larger, potential sales volume is generated. The market criteria contain all key data necessary for the assessment of the market situation.

Collating all applications of the case study

The new fields of application identified are displayed along with all their market factors relating to Germany as well as their technology characteristics based on the functional analysis, in figure 7. As shown, the applications address all the functions of the technology; however some attributes need some further development. The market potential is quite high for all applications however the competition intensity varies.

As the difference in research into growing animal as well as human organs is relatively small, these two applications will be combined in further analysis.

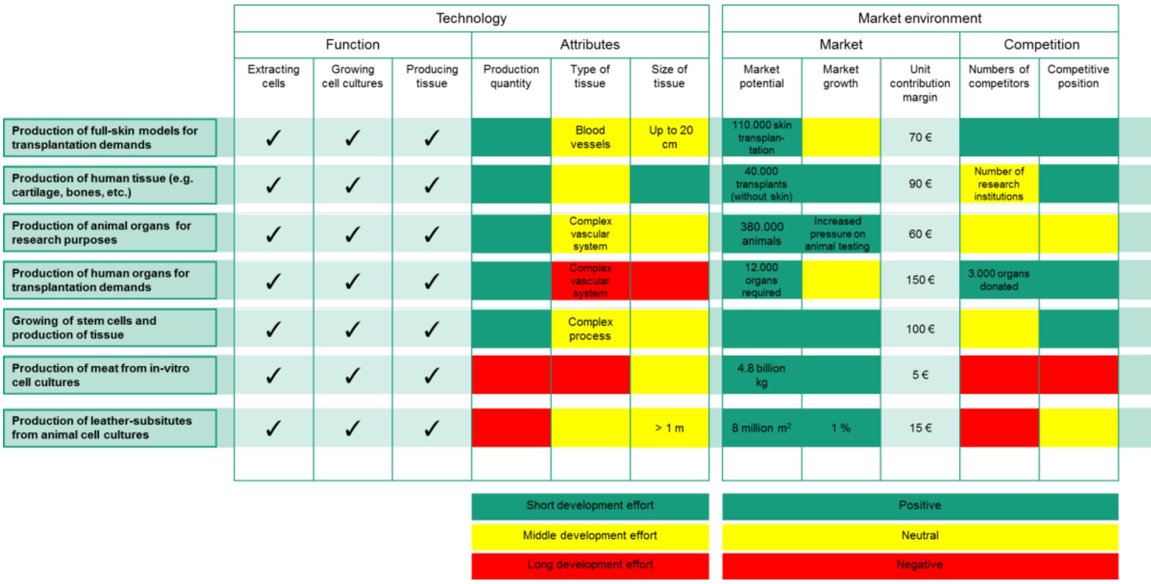

Fig. 7: Collection of all applications of the case study

3.5. Selection and evaluation of the applications

The potential applications can now be evaluated in terms of their benefits for the company using the identified market and technology characteristics. The aim is to further reduce the number of possible applications and identify their capabilities. For this purpose, a three-dimensional portfolio is used, which is characterized by the axes of market attractiveness, competitive intensity and further development intensity of the technology [54].

Market attractiveness describes the total market potential as well as the growth of a technology market. Competitive intensity determines how many competitors are present in the market and to what extent the application can be addressed with the existing technology. Further development intensity provides information relating to the point in time at which the product can be addressed using currently available technology.

The portfolio approach can then be adopted in order to further limit the number of applications identified. Applications with only a low level of market attractiveness or very high competitive intensity appear not to be worthwhile. Very high market attractiveness and low competitive intensity seem to be optimal elements guiding the decision to pursue successful technology commercialization, especially if the applications can be addressed with low or medium development intensity.

If the potential applications are reduced to a manageable number, a detailed assessment can be carried out. For this purpose, each application is analyzed and evaluated separately using the model of technology exploitation. Taking account of the identified market indicators for each application as well as the other sub-models, an assessment of the different exploitation options is possible.

Assessment of the applications in the case study

The potential applications are now transferred into an assessment portfolio taking identified market and technology factors into account (see Fig. 8). Due to the high market potential, low competition and low further development intensity, the production of full-thickness skin models appears to be well worth pursuing. Working with stem cells is evaluated very positively, too. It is envisaged that the production of human tissue will also be feasible and will require relatively little development effort; however the market volume is significantly lower than that of full-thickness skin models. Although the growth of complete organs may be promising and has enormous potential, it is not desirable due to the anticipated very lengthy research requirement. The same applies to the production of meat, especially due to the very extensive competition and the difficulties in relation to acceptance. Leather would also have a large potential, however the strong competition is seen negatively.

The assessment could also further narrow down the potential application areas, leaving only the three areas production of full-thickness skin models, stem cells for tissue production and human tissues such as cartilage and bones to be considered and assessed as exploitation alternatives.

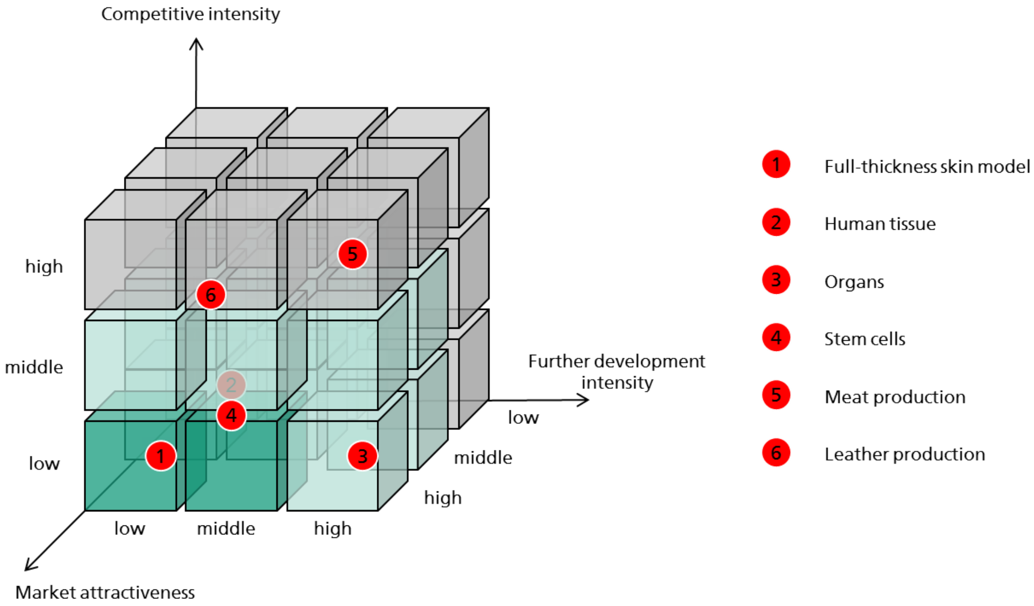

Fig. 8: Assessment portfolio of the case study

IV. Integration in the model of technology exploitation

On the basis of the technology, we identified several applications and evaluated their market in the previous section. However the main question for the exploitation decision is, how best to address the market. Each exploitation option offers advantages and disadvantages and the main challenge is to identify the right one for the selected applications. The applications are therefore transferred to the model of exploitation.

It has to be considered that each application has different characteristics. They are used in different markets, with different market volumes, sales prices or environmental factors. Furthermore, the technology characteristics identified differ depending on the operation concerned. Therefore each sub-model has to be described separately for each application.

Using the developed Excel tool of the exploitation model, each application can be assessed in terms of possible exploitation options. The outcome is a ranking of the exploitation options indicating the suitability of each application.

Results of the case study

The identified applications were transferred and assessed in the model of technology exploitation. A specific goal system has been developed by experts of the FhG with the focus on the maximization of financial returns, technological development as well as access to the developed know-how (see Fig. 9).

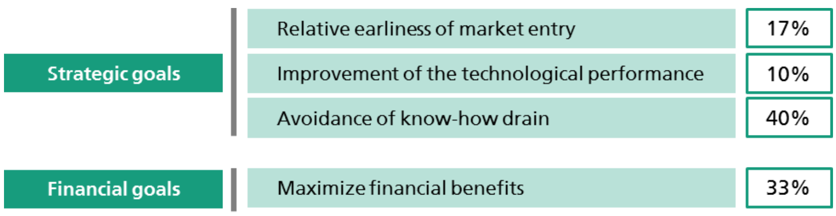

Fig. 9: Goal system of the case study

For the evaluation of the real market, the potential sales figures in Europe for each application were estimated. The technology life cycle is used to assess the extent and duration of the development performances. All three identified applications are still at the stage of growth, but the development intensity required, appears to be small to medium. However, significantly longer research, development and especially approval processes are anticipated in the health care industry.

The technology model was fine-tuned for each application. However since all three are very similar and totally new, the characteristics are the same. The technologies were developed within the FhG, all are at an early stage of their development process and they are classified as having huge potential. These technologies can, therefore, be considered as high complex pacemaker and core technologies with IP protection, shown in Fig. 10.

Characteristics	Specification		
Competitive relevance	Pacemaker technology	Key technology	Basic technology
Functional relevance	Core technology	Support technology	Irrelevant technology
Technology complexity	Simple technology	Complex technology	
Technology protection	IP protection	No IP protection	

Fig. 10: Technology model of the case study

By including all relevant data, it is possible to conduct a situation-specific assessment of exploitation alternatives using the Excel-tool developed. An individual calculation is performed for each of the three identified applications. The results are presented in Fig. 11 in the form of rankings for the most suitable exploitation options.

Production of **Full-Thickness Skin Models** for transplantation	
Internal utilization	33,33%
R&D cooperation	20,65%
SWORD	16,99%
Spin-Off	8,24%
Licensed Venture	7,91%
Joint-Venture	7,30%
Licensing	3,55%
Technology sale	2,02%

Growing of **Stem Cells** for producing human tissue	
Internal utilization	31,85%
R&D cooperation	21,59%
SWORD	17,29%
Spin-Off	8,09%
Licensed Venture	7,78%
Joint-Venture	6,93%
Licensing	3,94%
Technology sale	2,54%

Production of **Human Tissue** (e.g. cartilage, bones, etc.)	
R&D cooperation	28,08%
SWORD	19,80%
Internal utilization	19,71%
Spin-Off	7,39%
Licensed Venture	6,74%
Technology sale	6,56%
Licensing	6,10%
Joint-Venture	5,62%

Fig. 11: Assessment of the exploitation option for the three applications

For the production of full-thickness skin models and stem cells in-company utilization appears to be the most appropriate alternative. R&D cooperation and SWORD also seem to be very advantageous, whereas the other exploitation options achieved significantly lower rankings. For the production of human tissue on the other hand, R&D cooperation is by far the best exploitation alternative. SWORD and in-company utilization are considered to be almost equal.

The similarity of the results in this case can be explained by the fact that the applications can be found in similar industries and that market size and development time do not differ fundamentally from each other. In addition, all three applications have the same technology characteristics.

V. Conclusion and further research

Shorter product and technology life cycles have resulted in a requirement for rising technology investments to be amortized within a steadily diminishing period. Thus, companies are compelled to seek maximum commercialization of the technological potential at an early stage. The model of technology exploitation presented here provides a methodology to facilitate situation-dependent, appropriate decision-making in technology exploitation. Market-related factors were embedded in the exploitation model and it has been shown how potential markets that can be addressed using existing technology potential can be identified and evaluated. The model developed permits the exploitation options to be prioritized taking account of all relevant factors.

The developed methodology is a model-like approach to solving the very complex problem of technology exploitation. However, real exploitation decisions consist additionally of a wide variety of different influencing factors which could not previously be mapped. Nevertheless, we offer an effective tool for analyzing potential situation-specific exploitation alternatives. Whether the results can be applied in practice must be decided following rational consideration like in any other model-based valuation.

The functionality of the model developed was validated on the basis of the case study presented. Using a structured process it has been demonstrated how new fields of application can be identified and evaluated in terms of their exploitation potential on the basis of an existing technology. In the process, it has been shown that the model of technology exploitation involves a highly complex decision-method and that, in addition to company specific target weighting, due consideration must be given to market and technology factors in particular.

The process of structured identification of potential sales markets on the basis of existing technology potential also reveals some potential for optimization. There is a noticeable lack of efficient technical software for the analysis of databases using text analysis software. Although there are some providers, search engines and databases that address these problems, a complete structured and integrated approach for the identification of market potentials is not yet commercially available.

Overall, it can be assumed that the need for a complex decision-making methodology for technology exploitation will continue to increase thereby creating a gap to be filled by improvements generated in future research activities.

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