A Comprehensive Model for Socio-economic Technology Analysis and Evaluation

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Abstract

Successful innovation not only requires valuable new ideas but also their successful implementation into the market place in the form of resulting new products or processes. This diffusion is fuelled by technology acquisition decisions on the company level. The goal of this paper is to develop a conceptual comprehensive managerial model for these decision processes.
The model is developed and verified based on empirical data collected during a research project together with six European high-tech companies in the field of machine tools. The NanoSteel project deals with the industrialization and market introduction of a new machining technology consisting of ultrasonic assisted turning (UAT) with mono-crystalline diamond tools. The foundation for the developed model lies in a generic company model for organizational change. Relevant factors are distinguished to enable a thorough look at the process of technology assessment encompassing quantitative (financial and technological) and qualitative (intangible) benefits. Research results show that several aspects (e.g. functional, economical, social, environmental factors) have to be considered in order to develop specific managerial guidelines for this acquisition process for new technologies.

1. Introduction

New technologies can create new opportunities and represent a major source of competitive advantage and growth for manufacturing firms. However, successful innovation not only requires valuable new ideas but also their successful implementation into the market place in the form of new products or processes.

Looking at manufacturing enterprises it is obvious that production methods play a key role in terms of the functionality and reliability of the finished component. Therefore the machining operation must be regarded and designed as a high performance process to allow for increased productivity and quality. A precondition for exploiting this performance potential is a careful matching of the properties of the component with the machining conditions. This in turn demands precise knowledge of the specific performance behavior of the production technologies as well as its impact on the organization.

In addition the business environment of manufacturing enterprises will increasingly be characterized by change and complexity. Therefore changeability, as the potential of effectively

coping with unpredictable events, even beyond the planned corridors of flexibility, is thus viewed as the competitive lever for manufacturing enterprises. Production is consequently the key for creating sustainable fast reacting and adaptable business structures in order to face the future turbulent market environment. By advancement and optimization of conventional manufacturing technologies (e.g. grinding, polishing) mainly incremental changes are possible while, through the development and introduction of new procedures radical improvements can be obtained. The selection and planning of production technologies has important influence on the product design and functionality (efficiency, life span), further through the technology decision the productivity is determined. Thus the technology selection becomes an important factor for the competitive ability of producing enterprises, which entail large potentials as well as large risks. By the ever larger number of available technologies the pros and cons for specific cases of application are not immediately evident and make the selection of successful technologies increasingly more difficult. Particularly in an early phase of the technology development uncertainty over the potentials and effects exists. Additionally, new approaches and measures are needed in order to identify the appropriate time for change, to correctly manage the change process and to evaluate the resulting effects and value of changeability.

Hence, the ability to evaluate and assess technologies emerges as a key ingredient of technology acquisition decisions on the company level.

1.1 Research Methodology

Ultimately this paper aims to develop a conceptual comprehensive managerial model for technology assessment as a key element of technology acquisition decisions and as such support of corporate decision makers in selecting and implementing new (manufacturing) technologies.

The model is developed and verified based on empirical data collected during a research project together with six European high-tech companies in the field of machine tools. This project deals with the industrialization and market introduction of a radically new machining technology consisting of ultrasonic assisted turning (UAT) with mono-crystalline diamond tools. This innovative technology allows us to manufacture ultra-precision steel parts with complex shapes more efficiently than existing technologies. At an early prototype stage customers had been selected to play an active role in finalizing the technology and assessing its various impacts for their companies in general and their production environments in particular. In four end user case studies the technical feasibility, potentials and limitations of the new technology based on selected reference products are assessed in comparison with competing current and future production methods. In addition a market survey had been conducted to get insight into the market potential of the new technology and hence a first idea regarding its future diffusion.

The foundation for the developed model lies in broad organizational models such as the management model of the University of St. Gallen in Switzerland. In particular one generic company model for organizational change, developed by Wojda has been used as a basic structure and adopted to the very aim of technology assessment. Since technology decisions are challenged by a number of diverse factors, of which only a few are considered in everyday decisions, the leading idea is to transfer the comprehensive approach of those corporate models to the level of technology justification by the identification and/or definition of relevant socio-economic factors.

We define technology assessment as the future oriented assessment of the likely impacts of technological innovation on both the corporate and society level. So besides technological feasibility and economic efficiency further human and environmental effects will be considered.

From an early stage technological development can be influenced in a way to fulfill human needs and to avoid or minimize negative side effects.

Based on the results from the following case study this approach will be adapted and enhanced for the purpose of technology assessment. Its main idea – to encompass technical, organizational, and human related effects – will be transferred from corporate change in general to the introduction of a new technology.

2. Case Study

2.1 Introduction

Despite a significant demand for ultra-precision steel parts, the problem of identifying a finishing machining operation capable of machining complex parts with extremely high quality specifications has not yet been solved to a satisfactory degree.

The NanoSteel project addresses the above mentioned issues by offering an innovative technology of ultra-precision steel machining based on an ultrasonic assisted diamond tool system that replaces the traditional finishing methods. The applied method is based on using ultrasonic excited diamond tools for accurate finishing in computer numerically controlled (CNC) turning processes. The project was set up to develop a new diamond turning tool system for the manufacturing of ultra-precision steel parts with complex geometry. The overall aim is to enhance part quality and to produce part contours, which were previously regarded as impossible. Ultra-precision technology in combination with the use of mono-crystalline diamond tools presents a potential solution for the need to bridge this technological gap. At the same time a new process chain with reduced need for time-consuming finishing operations offers potential to decrease overall manufacturing costs.

2.2 Project Steps for Technology Assessment

Data collection is done with explorative semi-structured interviews of employees at different organizational levels of companies involved with this technology. Possible categories of interviewees are: product manager, production manager (plant manager), member of process planning department and machine operator. The interviews followed a semi-structured model and lasted about 90 minutes each. They focused on actual practice, potential for improvement, expectations in the new technology (and expected changes), and experienced changes throughout the implementation process.

A literature review and additional desk research have been done to find relevant evaluation models pertaining to new technology introduction.

A questionnaire based market survey has been carried out in order to verify and develop ultrasonic assisted turning technology according to manufacturer specific requirements. Important information of current situation and future requirements regarding precision machining of turning parts could be obtained. This enables one to estimate the potential regarding possible applications and relevance (diffusion) of the new technology in relation to competing current and future production methods.

3. New Conceptual Model

Using empirical data from the NanoSteel project as well as considering the main ideas of the new management model from the University of St. Gallen (Rüegg-Stürm, 2002) the corporate model by Wojda has been developed into the following comprehensive technology assessment model (see Figure 5).

It consists of two basic levels situated around the main business process affected by the new technology namely the (operational) assessment level and the effect level. The underlying foundation is the environment, which will be effected by changes in the business process (or its subsequent effects on the organization).

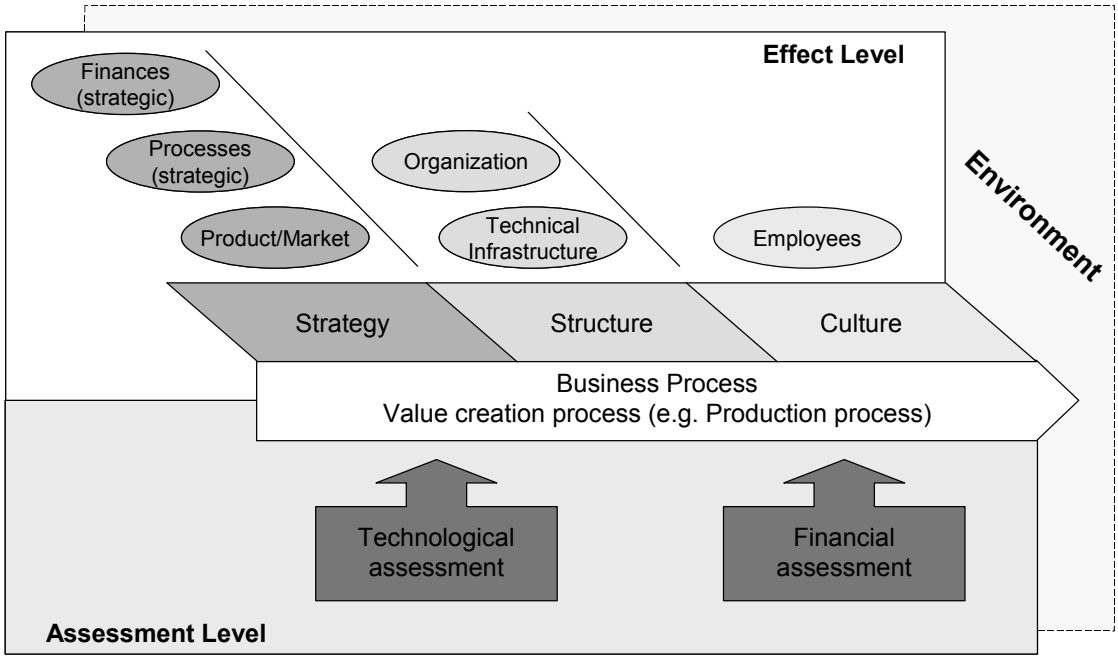


Figure 5: Comprehensive Technology Assessment (CTA) – model

3.1 Assessment Level

At the assessment level the direct operational decision takes place. The new technology has to be assessed in a technological as well as financial way.

Technological assessment
A comparison of the new technology with existing ones and/or certain target values in respect to technological characteristics is the main activity. A basic distinction for technological assessment is that in qualitative or quantitative criteria.

For the NanoSteel project an example for an quantitative analysis has been the comparison of the overall process times between existing production methods and the new ultrasonic assisted turning technology.

Financial assessment
For the evaluation of financial aspects a basic clustering in static and dynamic methods can be introduced.

3.2 Business Process

In between the two levels – building the centre of the decision – sits the relevant business process, (for the specific case study of this paper the production process).
The main question here is if and how the new technology will affect the main business process?

In the case of ultrasonic assisted turning there are substantial effects for the production process since this new manufacturing technology will allow to substitute or reduce the finishing process step and is therefore able to reduce the process chain. There are also influences on the overall process duration and the quality level of the resulting products.

3.3 Effect level

Besides the two main factors (technology and cost) of the technology there are also broader consequences that have to be considered as well. These factors build the effect level of the model. The following lists the main factors within the three clusters strategy, structure and culture.

Strategy

***Product/Market**:* Here implications on product range are addressed. The new technology may offer chances to produce new products and conquer new market-segments or gain additional market share. This may also influence customer structure, production programs and service requirements. A vital element of any change in product offering is also a thorough competitive analysis.

Processes: A company's core competencies may also be influenced by the introduction of a new technology. Therefore, the strategic alignment of a changed business process with a technology strategy has to be checked and, if necessary, adjusted.

Finance: The strategic part of financial analysis mainly refers to the decision among different types of financing (e.g. via equity or liabilities).

Structure

Organisation: Elements to be considered are types of tasks and required competencies, management structure and leadership as well as individual vs. group work. Also it may be necessary to adjust compensation schemes.

Technical infrastructure: Especially plots, buildings and facilities but also information and communication technologies and systems (ICT) may be influenced by the decision to adopt a new technology.

Culture

Taking a socio-economic point of view, social aspects play an important role in complementing the technological aspects.

Employees: Primarily the required qualification but also the types of employment relationships build the underlying structure of this field. However as for any successful business process motivation, communication and corporate culture are highly relevant.

3.3 Environment

Issues of environmental protection and sustainable economics will continue to gain significance; the environmental friendliness of services and products will become a main selling aspect. The improvement of resource productivity (reductions in the use of material resources and energy), which in many areas could be raised by a factor of 10 or more (Hinterberger, Littke, Vogel, 1999), is a prerequisite for a sustainable macro-economy.

4. Procedure of Technology Assessment

The different levels of the above described model are to be dealt with using a process approach. The resulting process of technology assessment follows four steps (distinct steps, however executed in an iterative parallel way):

1.) With clear objectives, check technological and financial aspects on the assessment level
2.) Evaluate consequences for the business process
3.) Consider various impacts on strategy, structure and culture
4.) Reflect on implication for the environment and adjust decision accordingly.

The CTA-model is part of a broad technology implementation process starting with need identification and basic strategic sourcing strategies (e.g. make or buy decision) over the implementation process to the innovation diffusion. This paper focuses on the above described technology assessment part.

Besides the consideration of individual circumstances of the company in question (“situation oriented”) there are also external contingency factors, which have to be considered. A situative approach is therefore necessary that will influence the practitioner’s usage (priorities and potential adaptations) of the model. Possible external factors which have to be considered include:

- Specific industry aspects
- Market conditions
- Overall technology developments.

5. Summary

New technologies have substantial influence on the society and competitive ability of enterprises. Successful implementation of new manufacturing technologies depends on a wide variety of factors. Especially important is a clear understanding of the necessary changes through the technology in respect to the influenced fields of organisation and benefits, which can be achieved. These benefits must be expressed for all concerned people in order to achieve a high level of acceptance.

Technology assessment of the impacts of new technology on society requires individual analysis on the corporate level (decision of adoption). From assumptions about technology diffusion the socio-economic effects can be derived.

A new comprehensive technology assessment model for an integrated view of the effects of new technologies is presented together with the main steps of the according assessment process as guideline for corporate decision makers.

This technology assessment approach has been developed and applied in the NanoSteel project which main objective is to develop, test and validate an innovative method for the manufacture of ultra-precision steel parts with complex geometry.

Further research includes detailed descriptions of the proposed model as well as its improvement and confirmation through the collection of more empirical data. Based on that next level model an operationalization could take place as foundation for quantitative studies. Such studies could focus on model validation within different settings.

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