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# PROCEEDINGS

INTERNATIONAL CONFERENCE ON COMPETITIVE MANUFACTURING



### **30 JANUARY - 1 FEBRUARY 2013** STELLENBOSCH, SOUTH AFRICA

Organised by Department of Inustrial Engineering Stellenbosch University

# **COMA '13**



UNIVERSITEIT • STELLENBOSCH • UNIVERSITY jou kennisvennoot • your knowledge partner International Academy of Production Engineering

## PROCEEDINGS

International Conference on Competitive Manufacturing



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Global Competitiveness Centre in Engineering Department of Industrial Engineering Stellenbosch University Private Bag X1 Matieland 7600 Stellenbosch, South Africa Tel: +27 21 808 4234 Fax: +27 21 808 4245 E-mail: <u>dimitrov@sun.ac.za; corne@sun.ac.za</u>

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#### Method to Quantify Value Added and Employment Effects of Technology Shifts

W. Sihn<sup>1, 2</sup>, H. Gommel<sup>1, 2</sup>

<sup>1</sup> Fraunhofer Austria Research GmbH, Division Production and Logistics Management, Theresianumgasse 7, 1040 Vienna, Austria

<sup>2</sup> Vienna University of Technology, Institute of Management Science, Theresianumgasse 27, 1040 Vienna, Austria

#### Abstract

Companies are more and more confronted with a lack of skilled workers. Especially when dealing with technology shifts, it is important to analyse the effects on value added and employment within a companies' value added network in order to allocate resources adequately. According to a study conducted by the Boston Consulting Group and the World Federation of People Management Associations, about 46 million additional workers will be needed in Western Europe till 2030, and 26 million workers in the United States respectively, mostly highly skilled workers. Therefore one recommended course of action is the introduction of a strategic human resource planning method in order to evaluate human resource needs within technology management.

This paper aims on setting up the framework for a method to determine value added and employment effects by linking technology management methods with existing human resource management methods and macroeconomic models in order to quantify a company's future demand for workers within their strategic HR-planning. The benefit of this method firstly is the usability of the model within strategic planning and decision processes compared to existing, highly complex macroeconomic models. Secondly it builds upon technology management methods, e.g. technology-roadmapping, that are already broadly used in companies.

#### Keywords

Human Resource Planning, Technology Management, Technology Roadmapping

#### 1 INTRODUCTION

The urge for companies to continuously track technological developments in order to evaluate the possibilities to use them for the company's success is, more than ever, existent [1]. Therefore, a large set of activities and methods within the field of "strategic management", or more precisely, "technology management" is utilised in companies, e.g. roadmapping, radar- and portfolio-techniques. An overview of the most important activities and methods is given in [2-5].

Technology management mainly aims at the emergence and utilisation of technologies, dealing with the sustainable entrenchment of technological know-how and capabilities within companies [3]. In order to assess emerging technologies in the early stages (early detection of technologies), technologyroadmapping is seen as one systematic approach, usable to represent the strategic technology plan over a long time period [2]. Based on the generic form of technology roadmaps proposed by EIRMA (European Industrial Research Management Association) [6], many different types of roadmaps have been developed, varying in purpose, format and use [7]. The purposes can vary from long range planning to integration and product planning and therefore generally entail the three levels "market", "product" and "technology", but can also be enriched by other levels, e.g. "skills" and "organisation".

When paying closer attention to the organisational level, it is important to take into account value added and human resource effects of the technology plan. Human resource management (HRM), therefore, needs to identify and manage the human resource implications of business strategies, and thereby technology plans [8]. This becomes especially important when looking at the findings of a study conducted by the World Economic Forum, estimating the demand for skilled workforce to the amount of additional 46 million employees in Europe in 2030, and 26 million workers in the United States respectively [9]. Unless а technological breakthrough replaces manpower, demographic developments and continuing average economic growth will therefore lead to major workforce and skill gaps, not only for western countries. To counteract this development, the authors of the study recommend countries and companies to effectively forecast both supply and demand of workforce over a long period of time.

The aim of this paper is to propose the basic framework for an effective method to determine value added and employment effects of technology shifts and to show results of the method exemplarily.

#### 2 PROBLEM FORMULATION

As discussed in the previous chapter, it is necessary to assess the future demand for employees within the company's business strategy. Strategic human resource management therefore focuses on linking human resource management with business strategy in order to design high-performance worksystems to gain sustained competitive advantage [10]. When it comes to the quantitative assessment of workforce demand, there are several different methods established in HRM, pointed out in the following [e.g. 11, 12]:

- Organisational methods that are based on staff appointment schemes, comparing future appointments to current appointments and eventually deriving the future demand.
- Forecast methods that are based on estimations, global demand prognoses, key performance indicators and capacity calculations.
- Other methods are based on established posts or monetary budgets.

However, these models do not or barely systematically take into account major technological shifts within the companies' strategy. On the one hand, this is due to the methods' focus on the operational level (e.g. organisational methods or forecast methods based on predetermined motion time system), on the other hand the methods are based on (adjusted) past data and therefore are not necessarily usable to assess human resource effects of technology shifts.

Human resource and value added effects of technology shifts, however, are discussed and analyzed within the field of public economies. In most of the cases, these models are based upon bottom-up analyses in combination with input-output analyses, e.g. in [13-15]. Due to their complexity and the high effort to set up these models, their usability within companies' human resource management is limited.

Berthel and Becker [16] summarize the general problems and limits of HR demand planning and discuss, for example, that

- the statistical significance of the companies' statistical values is only given by a sufficient basic population.
- the crucial detailedness of short-term analyses cannot be applied efficiently in long-term planning methods.

However, they recommend using available information within long-term HR planning as best as possible in order to continually improve these results the more it comes to short-term planning. In order to integrate technological information into human resource demand planning and in order to integrate quantitative human resource information in the technology strategy, this paper proposes the basic framework of a method linking different methods of human resource demand planning with the basic principle of technology-roadmapping. The method aims on filling the gap between existing models focusing on the short-term operational level and mostly estimation-based long-term strategic models or highly complex models of public economies, respectively.

#### 3 APPROACH

In the following, the basic approach will be described in two sections. Firstly, the technical and technological perspective, describing the approach to derive the relevant technical/technological information from technology roadmaps, or the requirements of the method concerning the detailedness of the roadmap. Secondly, the HR perspective, describing relevant key performance indicators in order to break down the technological information to workforce demand.

#### 3.1 Technical and technological perspective

As mentioned above, the basis of the technological perspective of the method proposed is the technology-roadmapping technique. This technique is "widely used within industry to support strategic and long-range planning" and "have a great potential for supporting the development and implementation of integrated strategic busines, product and technology plans", especially for the exploration and communication of the linkages between resources, objectives and the changing environment [7]. For the purpose of the method proposed, the multilayer roadmap, as the most common form, comprised of the dimensions timeframes and layers [17], is used (figure 1).

With regard to the timeframe the method aims to cover the long-term (typically ten-year) timeframe. Within this timeframe key uncertainties and scenarios are to be articulated, shifts in the technology, business and market environment to be explored.

In respect to the layers of the technology roadmap, the method mainly builds on the insights of the middle layer that generally relates to tangible systems that need to be developed whereas the results of the method are formally associated to the bottom layer that generally relates to resources.



Figure 1 - Hierarchical taxonomy of roadmap architecture [17]

When designing the technology roadmap, it is necessary to detail the products under consideration to at least the granularity of components or sub systems, so that they can unequivocally be assigned to corresponding industry sectors of the "International Standardized Industrial Classification of all Economic Activities" (ISIC) or the Statistique "Nomenclature des Activités Économiques dans la Communauté Européenne" (NACE), respectively. The NACE classification and description of sectors and belonging products can be found in [18], the ISIC classification in [19]. This allows the determination of industry specific indicators regarding value added quota and workforce productivity based on significant statistics in order to use them for the calculation of human resource demand. The assignment of components or subsystems needs to be done with respect to the basic technology within these components or subsystems and not with respect to the final product under consideration. For example, a new kind of electric motor for electric vehicles should be assigned to the NACE-class for the manufacturing of electric motors (NACE 2710) and not to the NACE-class for the manufacturing of motor vehicles (NACE 2910).



Figure 2 - Technology shifts and their effects on upcoming products (according to [20], cited by [21])

Another requirement in order to use the model is the granularity of the top layer of the technology roadmad, generally relating to external market and industry trends and drivers as well as internal business trends and objectives [17]. these business trends have to be broken down to expected unit numbers produced of the products covered by the technology roadmap. At this, the use of scenario techniques is recommended.

Finally, the production costs (i.e. the production value) of the components or subsystems under consideration have to be estimated. As these components are in very early stages of research and development, it is necessary to set up the cost function that models the cost development of the components over their lifecycle or the period of time covered by the technology roadmap, respectively. In order to model these cost functions, different cost degression effects, e.g. economies of scale/scope or learning effects, have to be considered. Within this paper, the cost function is abstracted as a function of unit numbers produced over the components' respective lifecycle.

Using the example displayed in figure 2, technology 1 (internal combustion propulsion system) is continually replaced by technology 2 (electric propulsion system). The short-term effect on the respective products is that conventional passenger vehicles are, for example, additionally equipped with electric propulsion components (e.g. start-stoptechnique). Due to the low unit numbers produced of these electric components, the production prices and therefore production values are guite high in comparison to electric components used in conventional vehicles. Because of the novelty of these electric components in passenger vehicles, no past data regarding value added quota or workforce productivity within the company is available. This lack of data can be handled by using indicators of industry sectors producing products with an analogue technological basis, in this case the electrics and electronics industry. In the ongoing course of this technology shift more and more conventional components are replaced by electric drive components (e.g. internal combustion engine vs. electric engine) with the effect that value added from the conventional vehicle industry sector shifts towards the electrics and electronics sector. The underlying human resource effects of these value added shifts can be calculated more adequately using the indicators of the newly addressed sector.

Using this data (production value, production numbers) for each of the components or subsystems identified, the total production value of the products covered by the technology roadmap can be calculated and unequivocally be assigned to corresponding industry sectors of the ISIC or NACE classification.

#### 3.2 Human resource perspective

In order to derive the human resource demand from the total production value of the products under consideration. industry sector specific the indicators concerning performance workforce productivity have to be determined. These statistics, structured similar to the classifications named above, are available for most of the industrialised countries. Workforce productivity in these statistics is measured to the basis of production value and gross value added. Section 4 of this paper shows the mathematical formulation on the basis of value added showing the relation between production value and value added as well.

The method therefore uses key performance indicators, like in [11, 12, 16], but by using industry specific indicators the problem of the lack of statistical significance of companies' data or the lack of statistical data itself within the company is avoided. By the assignment of production value to industry specific KPI's, major differences in the workforce productivity for the different industries are considered. For example, the workforce productivity within the sector manufacturing of basic metals (NACE 24) is much higher than the workforce productivity within the sector manufacturing of electrical equipment (NACE 27).

Due to the quantification by industry specific indicators the model has another major advantage compared to human resource demand forecasting models only using expert interviews or delphistudies. For long-term planning activities within technology management the accuracy of these values are satisfactory and can be refined for shortterm planning as soon as company specific data is available. Nevertheless, expert interviews are reasonable in order to validate the results of the model.

#### **4 MATHEMATICAL FORMULATION**

The basic mathematical formulation of the method's framework is described in the following.

# 4.1 Production value, gross value added and human resource demand determination on component level

The production value  $p_{i,j}$  of the *i*th product's *j*th component is mainly dependend on the unit number *u* produced (equation 1):

$$p_{i,j} = f(u) \tag{1}$$

The gross value added of the *i*th product's *j*th component derives from the production value  $p_{i,j}$  and the component's corresponding industry specific value added quota  $n_{i,j}$  (equation 2):

$$v_{i,j} = p_{i,j} \times n_{i,j} \tag{2}$$

Whereas  $n_{i,j} \in (0,1)$ 

The human resource (i.e. full-time-equivalent) demand of the *i*th product's *j*th component  $e_{i,j}$  from the gross value added  $v_{i,j}$  and the *i*th product's *j*th component's corresponding industry specific workforce productivity  $w_{i,i}$  (equation 3):

$$e_{i,j} = \frac{v_{i,j}}{w_{i,j}}$$
 (3)

# 4.2 Production value, gross value added and human resource demand determination on company level

The total production value *P* of the company's products considered at a certain point of time, or after a certain production volume respectively, derives from equation 4:

$$P = \sum_{i,j} p_{i,j} \tag{4}$$

The total gross value added V of these products derive from equation 5:

$$V = \sum_{i,j} v_{i,j} \tag{5}$$

The total human resource demand E of these products derive from equation 6:

$$E = \sum_{i,j} e_{i,j} \tag{6}$$

#### 5 EXAMPLE: EMPLOYMENT EFFECTS OF ELECTROMOBILITY IN AUSTRIA

Within the following example, the method of this paper was applied it now modify form, but still comprising the basic elements. Based on the expected market development of electric vehicle concepts, the components and sub-components of these vehicle concepts were assessed regarding their production costs and different unit number scenarios over the period of time under consideration as well as regarding to their respective industries sectors. By analyzing the Austrian automotive industry's position within the global production network, the Austrian market shares on the total production value of electric vehicles could be estimated and therefore the Austrian production value could be derived. Using the specific industry sectors statistical values regarding value added quota and workforce productivity, the human resource demand for electric vehicle production could finally be derived. Figure 3 shows the results for one unit number scenario analyzed within the study conducted by the Austrian economic ministry [22].





#### 6 CONCLUSTIONS

The aim of the paper is to show the basic framework of a human resource demand calculation method for technology-shifts based on existing models from human resource management and public economies. The major advantage of this model in comparison to the models or methods named above is that it is built on a technological basis derived from technology-roadmapping and that it uses technology specific indicators not necessarily available in companies, but on industry sector level. The method is suitable for semi-structured problems on the strategic management decision-making level of strategic and workforce planning activities [23].

As this paper is only a cursory description of the framework further research aims on the improvement of the model. For example, the determination of production prices, and production value respectively, at a certain point in the lifecycle of the product under consideration needs to be refined. Different costs degression effects or learning effects have to be modeled over the time in order to derive an adequate cost function. Furthermore, improvements concerning the differentiation of gross and net human resource demand as well as the assignment of competencies of the respective workforce have to be made.

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#### 8 **BIOGRAPHY**



Wilfried Sihn is Professor at the Institute of Management Science of the Vienna University of Technology and Head of the Fraunhofer Austria Research GmbH. His area of research is in the field of operation management.



Henrik Gommel is PhD-student at the Institute of Management Science of the Vienna University of Technology and researcher at Fraunhofer Austria Research GmbH. His research focus is on value added effects within technology management.



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CONTACT ADDRESS Stellenbosch University Department of Industrial Engineering, Private Bag X1, Matieland 7602, South Africa Tel:+27 21 808 4234 Fax: +27 21 808 4245 Email: dimitrov@sun.ac.za, corne@sun.ac.za

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