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A Method for Forecasting the Running Costs of Manufacturing Technologies in Automotive Production during the Early Planning Phase

M. Bornschlegl[a,*], S. Kreitlein[b], M. Bregulla[a], J. Franke[b]

[a]Research Centre, Technische Hochschule Ingolstadt, Esplanade 10, 85049 Ingolstadt, Germany
[b]Institute for Factory Automation and Production Systems (FAPS), FAU Erlangen-Nürnberg, Egerlandstr. 7-9, 91058 Erlangen, Germany

* Corresponding author. Tel.: +49-841-9348-5940; fax: +49-841-9348-995940. *E-mail address:* martin.bornschlegl@thi.de

Abstract

The running costs of production sites are a decisive factor in the overheads of automotive production. Because of this, it is important for many operators to decrease those costs in a sustainable way. Therefore, they try to reduce both the energy consumption costs of production systems, as well as their maintenance costs. However, most parts of the running costs are already determined during the very early phases of the product creation process. The approach in this paper shows how the decision for a specific manufacturing technology influences the factory costs. It is necessary to determine the life-cycle costs with regard to the manufacturing technology. Therefore, deep knowledge about the process itself and the support processes is required. This paper shows how cost relevant parameters can be identified and introduces a method to determine the prospective costs for maintenance and energy consumption in advance.

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Keywords: Factory planning; Holistic planning process; Life-cycle costing; Sustainable manufacturing; Running costs

1 Introduction

The increasing pressure to reduce CO_2-emissions brought on by stricter environmental laws, coupled with an increase in the customers' ecological awareness, means that many operators of manufacturing plants are interested in decreasing the energy consumption of production systems and, in doing so, the energy costs. [1] For this reasons, production systems should be planned and operated in a sustainable way. [2] That implies a consideration of the economic, ecological and social dimensions. [3]

The automotive industry is faced with the challenge to produce high quality vehicles in a reasonable time and at moderate costs. Therefore, the running costs of a production facility are a key factor in the economic efficiency of auto-motive production.

Especially for planning a body shop, the consideration of running cost are important, because the manufacturing technologies are set for a typical production period of about 7 years. [4] The biggest challenge thereby is to estimate the energy consumption of equipment. To get an overview of their own energy costs, the implementation of an energy management system (EMS), like it is described in the ISO 50001, is a first step. In its second year, 2012, the ISO 50001 on energy management has shown a growth of 332 % to 1.981 certifications in 60 countries and economies. In Germany the new energy policy of the government (German Energy Transition) was a main driver for these certifications. [5] Additionally, an energy key figure model, which adapts to the needs of the respective factory, is useful for the support of energetic optimization. [6,7]

Although the ideal of greener or even emission free production is proclaimed, the focus of many planners is still on cycle time, quality and costs. This is, among other things, due to the fact that there is a lack of useful and easy to use tools, which could support the planners and decision-makers.

To achieve all the above listed aspects, data, like energy consumption or amounts of spare parts, should be measured in detail to derive a better awareness of the operating costs of the manufacturing system. [6]

However, since every company or its divisions have different boundary conditions, it is necessary to conceive a stand-

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ardized approach, which supports mainly manufacturing engineers in the design of sustainable production facilities. So, a method for modeling the expected lifetime costs is necessary, which can specifically take into account the future energy consumption and therefore creates standardized and comparable key figures.

The rest of the paper is organized as follows: In section 2, related works are discussed and the requirements for a forecasting method for the running costs are listed. In section 3 the cost estimation approach is presented and section 4 shows the functioning of the decision support tool. In Section 5 the method is applied with a case study. Finally, the paper is concluded in section 6 and shows the tasks for future research.

2 Literature research and current situation

This section gives an overview of current research topics in the field of life-cycle costing (LCC) and predictions of energy consumption of production equipment in the automotive environment. Furthermore, the current planning process of the car industry will be shown, as well as the challenges and requirements for a tool to support sustainable planning decisions.

2.1 Current research about lifetime costs and energy forecast

Lifetime costs and their minimization in general is a well-known research topic and there have been several standards developed, like DIN EN 60300 or VDI 2884. [8,9] But most approaches focus on local measures and do not consider a holistic view of the whole factory system, which, as described in the asset management norms ISO 55000 ff., would be desirable. [10] With respect to the increasing awareness of sustainability in manufacturing, possible conflicts of objectives between different dimensions should be considered. [11] However, a holistic optimization over the life-cycle of car production and their manufacturing technologies are very complex and the results of them are difficult to determine. Due to this complexity there exists different approaches to reduce this to the necessary minimum. [12,13]

A further attempt is the combination of a discrete-event simulation (DES) with life-cycle assessment (LCA). For this purpose, DES has been adapted to calculate energy use and material losses. However, the modified DES requires substantially more total information than a conventional DES. [14] A similar approach is the streamlined LCA framework. This performance measurement system should help car makers to assess their technological options for sustainable mobility. This method requires companies to collect and interpret data on the environmental impact of used and alternative solutions. [15] Both methods provide mostly a framework, the collection of the necessary data applies to oneself.

In this context, the reduction of the CO_2-emissions is also often associated with life-cycle costs. The main focus will especially be on production emission in the coming years. Therefore, it is important that planners and operators achieve transparency in their energy consumption. And precisely here is the approach of a sustainable *Energy Chain* positioned, which considers all elements beginning from the energy supplier to the end customer. Additionally, the energy consumption is assessed, whether it is value-adding or not. This helps to find the levers to reduce energy consumption without reducing the level of quality and quantity. [16]

Another life-cycle evaluation approach for factories is presented, which is exemplarily applied to a case of a generic small enterprise from the metal processing industry. The main subsystems consist of production equipment, technical building equipment and building shell. How to generate the necessary data, especially for the manufacturing equipment, remains still open. [17]

There exists different LCC or knowledge-based approaches for special fields, like for electric motors, aircrafts or gas turbines. [13,18,19] However, these approaches are primarily suitable for these special applications and concentrate on the particular circumstances. Therefore, these methods are not transferable directly, for example to body shop planning.

In the field of simulation of energy-efficient production control, there are various approaches. Weinert designed with the *EnergyBlock* planning system, a methodology for production planning in relation to optimizing energy efficiency. The methodology divides the energy consumption of production operations in segments and linearizes the energy values. So, a specific energy consumption value is generated for each operating state of the production equipment. The application has been specifically tested for production systems with low complexity. [20] A further approach is the energy consumption prediction of a production system by using existing material flow simulation solution and expand them with energy values. Thus, a good approximation of the expected energy consumption can be achieved from common systems. [21-23] However, these approaches require a knowledge about the exact production equipment and their process sequences, both of which are not known at an early planning stage. In addition to the simulation approaches exists the *energy value stream mapping* (EVSM) method, which is derivate from the *value stream*. EVSM analyses the process and determines energy values for every step and tries afterwards to improve the energy efficiency. [24,25] Due to the structure of EVSM, it is also not perfectly suitable for the early planning phase.

The literature review shows, that although many approaches for life-cycle costing and energy consumption forecasting exists, it is challenging to determine the whole costs over the lifetime of productions equipment in the automotive production during the early planning phase. But right at this time, the highest potential is to influence the life-cycle costs, because about 70-80 % of the operating costs are committed during the concept stage. Influencing abilities are more limited and expensive the later they occur in the development cycle. [12] So, it would be helpful to know the running costs of different planning alternatives in advance and therefore this forecasting approach is designed.

2.2 Current situation in the automotive industry

The Product Development Process (PDP) in the automotive industry is highly standardized. In this process the planning and design of manufacturing technologies is also determined and this takes place about 50 and 6 months before the start of production (SOP).