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Integral Analysis of Labor Productivity

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Abstract

Analyzing and improving the productivity of labor-intensive manufacturing and assembly operations remains a crucial task for industrial companies. Because of the heterogeneous causes for productivity losses, the analysis requires a comprehensive data acquisition and evaluation. With this paper we introduce a state-oriented approach providing the possibility to identify and prioritize the different impacts on labor productivity for subsequent process enhancements. With a case study, we show how to visualize and evaluate state data of an assembly cell to establish a goal-oriented improvement process.

Keywords: Productivity analysis; Labor productivity; State-oriented modeling; Continuous improvement process

1. Introduction

Especially companies with manufacturing and assembly processes aim at adapting methods and tools provided through the lean production philosophy and other classical approaches to analyze and optimize their production [1]. A common goal is to establish a continuous improvement process to achieve the same added value with reduced resource utilization [2]. The decision on which optimization approaches are to be used as well as the order of their application is often based on the management's experience or actual trends in the practice of production management or lean production. This lack of transparency is a reason for ineffective improvement processes, applying methods and tools to selected areas of a production site without previous prioritization [3].

These shortcomings lead to the question, how transparency over productivity losses can be achieved in a way that enables the production manager to decide which problems should be approached with priority. This article presents a method for the comprehensive analysis of labor productivity in manufacturing or assembly environments.

2. Productivity analysis

The productivity is defined as relation between the output and the input of a production process [4]. The labor productivity as a partial productivity index typically describes the relation of the output of a process to the used capacity given in time units or the number of persons involved. The productivity management cycle formulated by Sink [5] consists of the four phases Measurement, Evaluation, Planning, and Improvement. For the purpose of this research work, productivity analysis is assigned to the first two phases.

Common productivity measurement techniques include productivity indices, econometric models and linear programming [6]. Measuring the total or partial factor productivity with indices enables the implicit description of a production function of any industrial company. The factor quantities and corresponding weighting coefficients may be determined empirically [7]. Econometric models also belong to the parametric measurement methods. In these models, specific characteristics for a company are formulated through altered error terms and both systematic and random deviations from an average production function [8].

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With nonparametric approaches, in particular the data envelopment analysis (DEA), the production function is derived from empirically collected input/output data and subsequent linear programming [9].

A problem with total and partial productivity indices is that the optimization potential is not indicated. Econometric models are equally based on assumptions regarding the form of the production function and require estimations of mathematical terms for company-specific adaptations. The data evaluation as part of the DEA is not suitable for prioritization of improvement projects without further considerable analysis effort.

Beside the named measurement methods, the relative productivity of a company may be determined through benchmark studies based on the analysis of financial key figures and through extensive acquisition of empirical data [10]. Transferring the introduced approaches to manufacturing systems is generally possible and has been done for example by Wan using the DEA [11].

However, two main disadvantages regarding the practical implementation of the methods remain: they yield abstract results through theoretic assumptions, i.e. assigning identified productivity losses to optimization fields is suggestive, and, with a low level of detail, they are only suitable for the mid-term and long-term adaptation of production processes.

In contrast, operational methods for the analysis and optimization of production processes rely on a high level of detail. A selection of methods includes predetermined time systems, set-up time analysis, sickness records, and breakdown time analysis. The approaches enable detailed analyses and, to some extent, the operational optimization of labor-intensive production environments with respect to productivity. However, these methods do not provide the data required for a comprehensive analysis of the labor productivity.

In summary, the two groups of methods yield results that are either too superficial or too focused. Additionally, both necessitate high effort for the data acquisition and evaluation. The designated method thus is designed for productivity analyses based on data with an above-average level of detail and a reduced level of data acquisition and analysis effort (see Fig. 1).

For a structured implementation of the designated method, an analysis framework has been developed. The scope of this paper includes the methodical elements data acquisition, data aggregation and data evaluation.

3. State-oriented modeling

State-oriented modeling focuses on the analysis of input data, i.e. the activities of the personnel employed in the production processes measured in time units. For a comprehensive description of the input in the form of human work, the concept of worker states is introduced.

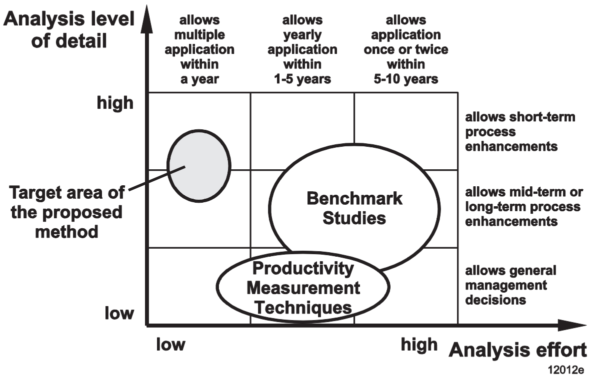

Fig. 1. Classification of the analysis approach

Worker states represent any planned or unplanned activities occurring for each person engaged in a production process. So far, state-oriented efficiency or productivity analyses have mainly been applied to machines or interlinked manufacturing systems [12, 13].

To realize a comprehensive analysis, the worker states need to cover the whole time span the personnel is paid by the company. Value-adding tasks as well as for example waiting and repair times can equally be a source for reduced labor productivity.

As a fundamental structure, a state hierarchy has been formulated to differentiate between certain types of worker states. They are grouped into four categories: cycle-bound, batch-bound, periodical, and irregular. In Table 1 the state categories are specified.

Table 1. Specification of worker state categories

State category	Description	Example
Cycle-bound	Represents all activities of workers occurring within one working cycle	Manual assembly step in a paced production line
Batch-bound	Represents all activities of workers occurring for each produced batch	Transport of material before and after the production of a batch
Periodical	Represents all activities of workers occurring periodically	Group meetings or planned breaks
Irregular	Represents all activities of workers occurring irregularly	Waiting time caused by equipment breakdown; absenteeism

Each category contains typical worker states. The worker state may be refined to enable the data acquisition and evaluation with a variable level of detail. The hierarchy of selected worker states of the cycle-bound category is depicted in Fig. 2. The sum of the state durations per category plus a term for not recorded activities equals the paid working time (equation 1).