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Systematic procedure for leveling of low volume and high mix production☆

Fabian Bohnen [a,*], Matthias Buhl [b], Jochen Deuse [a]

[a] *TU Dortmund University, Institute of Production Systems, Leonhard-Euler-Straße 5, 44227 Dortmund, Germany*
[b] *PA Consulting Group GmbH, Eschersheimer Landstraße 223, 60320 Frankfurt/Main, Germany*

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ABSTRACT

The application of conventional leveling approaches is limited to large scale production. This paper presents a systematic procedure for leveling of low volume and high mix production. It employs clustering techniques to group product types into product families. After that, a family-based leveling pattern is created which describes a repetitive sequence of capacity slots considering all families. According to the leveling pattern, each family is manufactured within a periodic interval. The paper provides a brief overview of the systematic procedure. It focuses on the creation of the leveling pattern using operations research methods and presents a real life application.

1. Introduction

Production leveling also referred to as production smoothing or heijunka is an essential element of the Toyota Production System and lean production, respectively [1]. The objective of production leveling is to balance production volume as well as production mix [1,2]. Hereby, production leveling decreases variation in form of peaks and valleys in the production schedule [3]. It enables companies to enhance efficiency by reducing waste, overburden of people or equipment, and unevenness [1].

The objective of production leveling is to balance production volume as well as production mix by decoupling production orders and customer demand [1]. Thus, work load in production and logistic processes is balanced [3]. Conventional leveling approaches aim at distributing production volume and mix to equable short periods [3]. The sequence of these periods describes a kind of manufacturing frequency. According to this leveling pattern every product type is manufactured within a periodic interval, for example a day or a shift [4]. The duration of this interval is depicted by the key figure EPEI (every part every interval). The EPEI-value is used as an index for reactivity and it also reflects lot sizes [5]. An EPEI-value of one day, for example, reveals that all product types are manufactured once a day.

Considering requirements of conventional approaches, leveling is predominantly utilized in large scale production. Nevertheless, it can be implemented in low volume and high mix production by means of an adapted leveling procedure presented here. The paper is organized as follows: after a brief literature review in Section 2, an overview of the procedure for leveling of low volume and high mix production is given in Section 3. This procedure consists of two fundamental steps. Section 4 deals with the first step. In this step product families are formed for leveling based on manufacturing similarities. Using these families, a leveling pattern is created in the second step. The methodology for leveling pattern creation is the focus of this paper. It is described in detail in Section 5. After that, a case study is presented in Section 6 and a conclusion is given in Section 7.

2. Literature review

Most of the approaches for production leveling described in literature concentrate on large scale production. Without reference to the application context, this literature can be divided into two classes. The first class focuses on procedure models, i.e. systematic procedures for leveling. The second class describes leveling as an optimization problem in context of production sequencing. The following subsections give a brief state of the art review on both, procedure models and optimization models for leveling.

2.1. Procedure models

For leveling of large scale production, several procedure models can be found in literature. Most of them describe procedures for leveling without referring to the application in specific industry sectors. Such models are presented in Monden [6], Shingo [7], and Takeda [8], for example. All of them use two-stage procedures. In the first stage production volume is distributed over equal-sized planning increments, such as, e.g. a day or a shift. Based on that, the second stage aims at harmonizing the production mix by

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* Corresponding author. Tel.: +49 231 755 4844; fax: +49 231 755 2649.
E-mail address: fabian.bohnen@tu-dortmund.de (F. Bohnen).

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determining a repetitive production sequence. Related procedure models are presented in Duggan [9], Erlach [10], Rother and Harris [5], Rother and Shook [11], and Smalley [12]. They also distribute production volume to planning increments in the first stage, but utilize a so-called pitch increment for sequencing in the second stage. This pitch increment is calculated as a product of takt time and packing unit. Wuthnow [13] develops a specific procedure model for leveling of electronic control units manufacturing in the automotive industry and focuses on production control aspects. The procedure models noted above concentrate on large scale production and provide implementation guidelines. They focus on the steps that are necessary for leveling. However, a detailed analytical description of the step of leveling pattern creation is missing. This is the most complex and therefore the most challenging step in implementing leveling. This can be seen as a major drawback of procedure models.

2.2. Optimization models

Most of the optimization models for production leveling focus on large scale production in form of synchronized mixed-model assembly lines. These models transfer the objective of leveling pattern creation, i.e. harmonization of production volume and mix, to an analytical level and refer to the so-called production smoothing problem (PSP). The PSP maps the objectives of leveling on a sequencing problem. It represents the problem of finding a production sequence that minimizes variation concerning one or more objective functions. Approaches aiming at solving the PSP are also referred to as level scheduling approaches.

Literature surveys on level scheduling approaches and related work are given in Boysen et al. [14], Kubiak [15], and Yavuz and Akcali [16]. These surveys provide a classification of literature dealing with the PSP that refers to the considered production levels and objective functions. A large amount of approaches only focuses on the final assembly level [17]. In this context, level scheduling approaches can be found that aim at minimizing variation in production rates [18,19], material consumption rates [6,20], or workload [21,22]. Additionally, there are some approaches aiming at minimizing more than one of these objectives simultaneously [23,24]. Among level scheduling approaches which only consider a single production level, production rate-related approaches are widely-used in literature. They are based on the assumption that the considered product types require approximately the same volume and mix of components and presume an unambiguous allocation of material and product types (i.e. there are no components which are used for more than a unique product type). Due to that, these approaches are not applicable for real life problems [25]. In contrast, material consumption- and workload-related approaches are more suited for industrial application.

Furthermore, level scheduling approaches can be found that consider more than one production level, e.g. final assembly and subassembly level. The latter mostly focus on the objective of minimizing variation in material consumption rates [26,27]. Additionally, some approaches combine this objective with those mentioned before [17]. The majority of level scheduling approaches concentrates on mixed-model assembly lines in the automotive industry. Referring to this application context, the respective optimization models are based on the assumption of homogenous cycle times per unit and they do not consider changeover times. Due to that, these models cannot be utilized to level low volume and high mix production. There are only a few papers outlining level scheduling approaches for flow shop environments [28–30] or single machine cases, respectively [31–33]. Though, it is important to note that these approaches also refer to large scale production and its characteristics. As a conclusion, an analytical approach has to be developed which describes the step of leveling pattern creation for low volume and high mix production environments.

3. Leveling low volume and high mix production

Production leveling typically requires limited product diversity combined with stable and predictable customer demand [3,34,35]. Due to that, the application of conventional leveling approaches (i.e. manufacturing every product type within a periodic interval) is limited to large scale production. Nevertheless, leveling can be implemented in low volume and high mix production by means of a systematic procedure which is presented in the following sections. An overview on the procedure is given in Fig. 1. It is based on principles and methods of Group Technology. It uses clustering techniques to group product types into families according to their manufacturing similarity. In other words, the large number of product types is grouped into a manageable number of product families (cf. Section 4). The objective is to be able to manufacture different product types assigned to one family without or with minimal losses caused by changeover.

Based on these families production leveling is realized. The result is a family-oriented leveling pattern which represents a leveled production schedule. This leveling pattern is generated by applying a systematic procedure that is adapted from large scale production (for more details see Section 5). This procedure employs operations research methods to determine sequence and length of capacity slots in the pattern. The methodology for leveling pattern creation is based on the assumption that leveling is applied at a well-defined bottleneck in the considered value stream. Additionally, this bottleneck is supposed to be a single aggregate or work station.

4. Product family formation for leveling

To implement leveling in spite of high product diversity, product types are grouped into a manageable number of families. Utilization of these families for leveling requires that product types of one family can be manufactured in an almost arbitrary sequence without or with minimal losses caused by changeover. Due to that, manufacturing oriented grouping criteria, especially criteria specifying similarities concerning production sequence and requirements, are used. The selection of grouping criteria essentially depends on the application context. In general, operation sequences, required equipment and staff, process times, setup times for changeover and the share of identical components, parts, or raw material represent adequate grouping criteria [34,36].

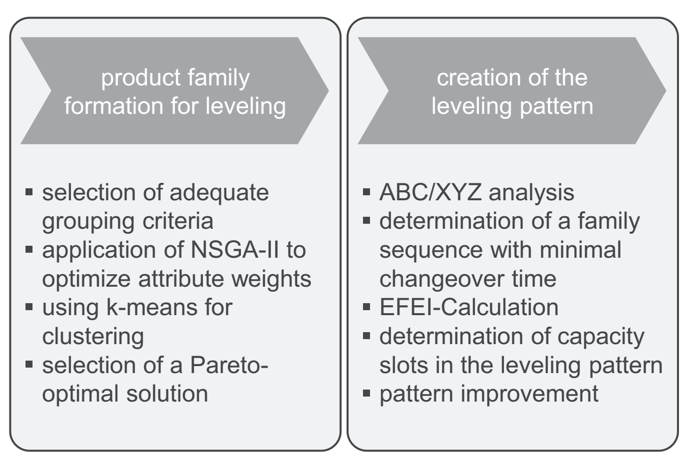

Fig. 1. Systematic procedure for leveling of low volume and high mix production.