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Volume and Mix Flexibility Evaluation of Lean Production Systems

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Abstract

This paper introduces a practice-oriented and field-tested approach to measure and evaluate volume and mix flexibility of a lean production system. After an introductory literature review revealing and classifying various types of flexibility as well as models to determine the flexibility of production systems, the most important flexibility types – volume and mix flexibility – are identified. Existing approaches for volume and mix flexibility evaluation are hard to implement in practice for different reasons: They are often bound to specific constraints or require extensive and complex input parameters. Additionally a lot of these models neglect the actual demand for flexibility.
Lean production systems strive for a reduction of throughput times by eliminating non-value-adding work. In a perfectly lean and flexible production system responding to volatile demands, time gaps between customer demand dates and production dates would be removed completely for every single order. The model designed therefore uses the capacity-weighted difference of demand and corresponding production in a restricted time period for each product variant in relation to the total capacity demand.

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Keywords: Lean Production; Volume Flexibility; Mix Flexibility; Production System

1. Introduction

Because of shorter product lifecycles and a rising product variety, the manufacturing industry today faces enormous challenges concerning the satisfaction of the customers' demand. Due to the growing dynamic and variation in demand modern production systems have to be lean and flexible in order to strengthen the company's competitive position [1]. Customers expect short lead times even when their demand changes. This means that a production system has to be able to adapt itself to a new market situation as fast as possible. Nevertheless a high flexibility also results in higher costs [2]. From an economic point of view this means that a lean production system should not be more flexible than absolutely necessary.

Until today various sophisticated models to evaluate manufacturing flexibility have been developed. However a lot of them are hard to implement in practice as they are limited to specific constraints. In this scientific paper a practice-oriented approach to evaluate volume and mix flexibility is presented.

Thus section 2 gives a short overview about a possible systematization of flexibility in production and existing approaches to evaluate it. A new approach which focuses on volume and mix flexibility is introduced in section 3 and then validated in section 4. The last part of this paper summarizes the main findings.

2. Literature review

2.1. Definition and classification of flexibility

Before taking a closer look at the measurement of flexibility it needs to be determined what flexibility in the area of production actually means. In literature numerous definitions of flexibility can be found (see [3], [4], [5]). Due to different research focuses most of them describe flexibility in a slightly different way. In order to

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ensure a common understanding we refer to the perspective of DE TONI and TONCHIA [6] who describe the flexibility of a manufacturing system as its capacity to move quickly and with little penalty in time, effort, cost or performance from one state to another in order to respond to changing requirements. A similar definition can be found in NYHUIS et al. [7] who define flexibility as the ability to realise changes within a certain band width which has been predefined in the planning phase of the production system in order to react to expectable variations for example in demand.

Another important aspect regarding the evaluation of flexibility is its systematization. ELMARAGHY [8] lists 10 different types of flexibility referring to BROWNE et al. [9] and SETHI and SETHI [10]:

- Machine flexibility
- Material handling flexibility
- Operation flexibility
- Process flexibility (also known as mix flexibility)
- Product flexibility
- Routing flexibility
- Volume flexibility
- Expansion flexibility (recently also known as reconfigurability)
- Control program flexibility
- Production flexibility

SEIDEL and VON GARREL [11] conducted a survey to evaluate the root causes of the demand for flexibility. 1221 companies took part in this study. The most important reason for the companies to raise flexibility in their production system was the ability to react to a changing demand (see figure 1). This means that volume and mix are the most important types of flexibility as they determine the capability to adapt to the customers' needs. This finding is also supported by SUAREZ et al.

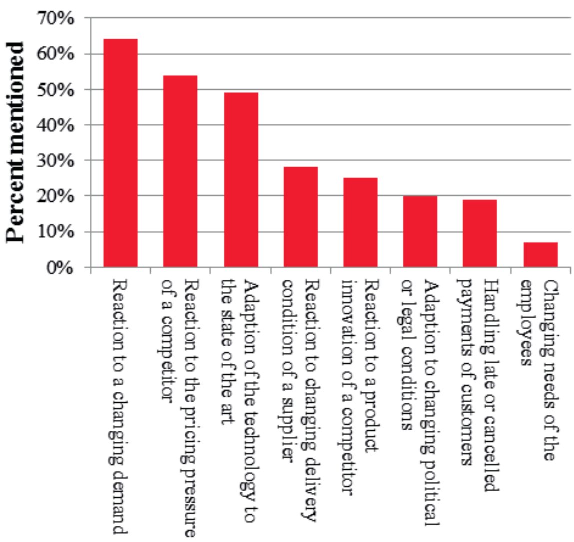

Fig. 1. Causes for Flexibility Demand [11]

[12] who define volume and mix as first-order flexibility types. Therefore this paper focuses on these types. In doing so the term *mix flexibility* represents the same type as *process flexibility* [9].

Looking for models in literature to measure flexibility one can distinguish between the ones which comprise several types of flexibility and the ones which concentrate on only one flexibility type. Examples for the first category are the *Overall Equipment Flexibility (OEF)* by ABELE et al. [2] or the toolbox approach of GEORGOULIAS et al. [13]. Examples for the latter category are introduced in section 2.2. and 2.3. Another classification of existing flexibility measures can also be found in GUPTA and GOYAL [14] who describe qualitative and quantitative flexibility measures.

As this paper introduces an approach to measure and evaluate volume and mix flexibility, a short overview about existing models in these domains will be given.

2.2. Selected existing approaches in volume flexibility evaluation

Regarding a Flexible Manufacturing System (FMS) volume flexibility "is the ability to operate an FMS profitably at different production volumes" [9]. This section describes exemplarily the approaches of PARKER and WIRTH [15] as well as the approach of DAS [16] to evaluate volume flexibility. Further approaches in this domain were introduced by BEAMON [17] or SETHI and SETHI [10] for example.

According to PARKER and WIRTH [15] every production system has a range of profitable output quantities. This range is limited by the break-even volume and the output capacity. The greater the difference between these limits, the higher is the volume flexibility of the production system. For *n* products it is calculated by formula (1).

$$VF = 1 - \frac{F}{C_{\max}} \left(\prod_{i=1}^{n} \frac{a_i}{b_i}\right)^{1/n} \quad (1)$$

VF: volume flexibility
F: fixed costs
C_{max}: production system capacity
a: required amount of capacity units to produce one product unit
b: contribution margin of one product unit

Like PARKER and WIRTH, DAS [16] also determines volume flexibility by using the profitable range of product output. However he does not see the break-even point as a good measurement for the lower limit because a manufacturing facility with a lower capacity would be more profitable in this point than one with a higher capacity. Therefore he looks at a hypothetical manu-