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Predictive production planning considering the operative risk in a manufacturing system

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Abstract

Customers' ever more stringent quality requirements, continually shrinking product-life-cycle durations, and a rising number of variants confront manufacturing companies with new challenges. Reliable production is fundamentally important for any industrial company attempting to address these challenges. An effective risk management system helps to ensure such production. The ongoing digitization of production systems also yields new possibilities for evaluating production risks such as machine failures or delivery delays. Especially the growing number of sensors in production systems increases the availability of data for a manufacturing system. This data can be employed to more precisely recognize process related, operative risks during the production process. This offers the opportunity to act on possible risks during production planning and control (PPC). PPC-like sequencing or machine scheduling can hence be applied to reduce risks in a manufacturing system. We therefore present a new approach for a production planning system taking a production system's actual risk level into account. Risk identification in and modeling of a production system is therefore proposed. The evaluated risk then has to be integrated into the planning procedures to reduce the risk level in a manufacturing system. A prototypical application scenario is subsequently presented to demonstrate the approach's feasibility.

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Keywords: manufacturing, modeling, methodolgy;

1. Introduction

Companies nowadays are finding themselves in an exceptionally turbulent market environment [1, 2]. In contrast to the past, when national boundaries restricted the market and constant product-life-cycle durations prevailed, the customer now demands new, usually customer-specific products at constantly shorter intervals, which ideally should be available immediately. Companies operating both inside and outside of the automotive industry are concentrating on their core competences and transferring other production steps to their suppliers to meet these requirements. This trend, along with steadily declining logistics costs, has led and continues to lead to the development of production networks that can be distributed globally [3, 4, 5]. This, however, constantly increases the complexity of the logistic processes in these networks and entails different risks for the individual companies involved. Such a risk can be the failure of a supplier due to a natural catastrophe and the ensuing delay in the supply of required raw materials. A supply-chain risk management system can help to reduce risks originating from the cooperation of multiple companies. On the other hand, it is useful to reduce the uncertainty, and thus the risk, that prevails in each individual company. [6, 7]

Companies are also faced with different challenges due to the increasing complexity of their own production processes. Increasingly digitized production, for example from integrating smart devices such as tablets, smartphones, or intelligent sensors, can enhance production efficiency but can also create new risks for the company's production [8, 9]. Such risks must be taken into account and diminished to minimize their impact on target quantities. Such risks are ideally considered during the early stages of the production planning process. Nevertheless, some risks that originate during short-term production phases can only be taken into account within the pertinent production-planning phases such as scheduling or sequencing of customer orders [10].

This article presents an approach taking into account operational risks that may arise in a company's production. The

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necessary elements of risk identification and quantification, system modeling, and integration into production planning are suggested.

2. Risk management in production systems

2.1. Definition of risks

The literature defines the term "risk" in many different ways depending on the domain of each approach. In principle, a risk can be regarded as a danger as well as a chance, thus a positive deviation from the targeted key performance indicators (KPIs) [10, 11]. This aspect, however, is ignored in this article. Only negative target deviations are focused on here. According to [12, 13], production risks can be understood as all negative target deviations. The causes of them occur with a certain probability, and their potential consequences can be seen on a company's shop floor. Risks can be quantified by multiplying their occurrence probability by the extent of damage inflicted when they occur. Production risks can be realized in more detail by chronological classification. Corresponding to the different phases of PPC, production risks can also be differentiated into strategical, tactical, and operational risks (see Fig. 1). Production risks can be categorized into production factor risks, production process risks, and product risks [12].

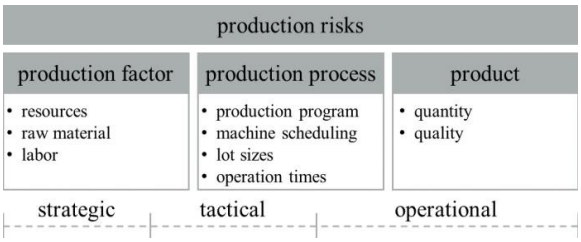

Fig. 1 Categorization of production risks and chronological presentation

Material being ordered late or quality defects in raw material can represent production factor risks. An example of production process risk is a deviation from planned cycle times while manufacturing a good. Among product risks are those involving failure to reach the finished products' quality or quantity targets. An example of this is the delayed completion of a customer order [12, 13].

In accordance to the aforementioned possibilities and tasks of production planning, this article focuses mainly on operational production risks since the means of production planning, hence production process and product risks, can influence these.

2.2. Risk management

Risk management is an iterative process that can be divided into different phases which will be described in the following chapter [14].

Existing risks have to be identified first. The identified risks then have to be assessed. Risk prioritization during the second phase highlights the enterprise's most threatening dangers. The complexity of this task mustn't be underestimated. Interdependencies between several risks often lead to complex risk situations on the shop floor. During risk-treatment phase, measures have to be chosen and executed to reduce the probability of occurrence and the attendant degradation of key performance indicators such as workload or adherence to delivery dates. The last phase of the risk management cycle involves monitoring the previously treated risks. Hence, the effectiveness of the authorized measures is measured during this phase. An overview of several methods applied during aforementioned phases of risk management can obtained from Fig. 2. [11, 14]

Operational risk management deals with all of the risks resulting directly from a company's processes whereas strategic risk management is tightly linked to strategic corporate planning and focuses on long-term developments and risks [15]. The approach presented here can be assigned to the operational-risk-management category because it enables risks originating from the shop floor to be dealt with.

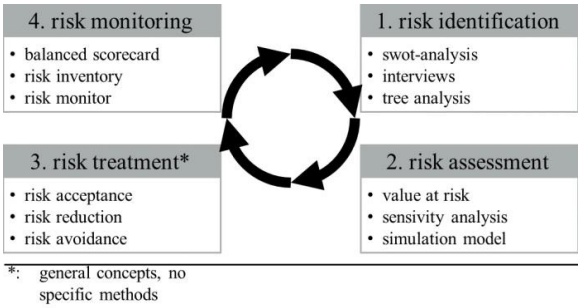

Fig. 2 Risk management phases and respective methods for each phase

2.3. Requirements for production planning

Risks arising from resource allocation or the production plan's composition must be taken into account and influenced during the production planning phase [16]. Offering a model of the production system under consideration is necessary for this.

Hence a modeling language has to be chosen that accommodates the needs of production-planning algorithms as well as those of algorithms for identifying and quantifying production risks.

For example, different levels of abstraction have to be possible in a given model depending on the depth of detail required to identify the risk associated with individual resources in the production system. Furthermore, the identified risks' probabilities of occurrence and extents of damage must be quickly determined to enable production planning to take them into account. Assigning the different risks or risk categories (see sec. 2.1) to the different planning steps such as sequencing or lot size determination is very important when doing so. Furthermore, suitable modeling has to be developed for uncertainty to enable existing risks to be measured. Taking into account the company's or decision maker's risk-taking behavior to create different production plans must also be possible.

3. State of the research

PPC's central task is to plan and control production. The target values that have to be considered during this task are the adherence to delivery dates, short cycle times, and intensive,