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Towards the Investigation of Production Order Interdependency Effects on Logistics Performance

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Abstract

Manufacturers continuously face the challenge of driving down costs while being subjected to increasingly globalized market pressures to shorten production lead times and increase delivery reliability. The early prediction of the expected logistics performance of single production orders as well as for the entire manufacturing system is a pivotal strategic corporate activity. However, companies frequently find themselves struggling to foresee and integrate operational dynamic effects related to production orders into production planning decisions. Such dynamic interdependency effects between orders in close temporal and spatial neighbourhoods can have an impact on logistics performance. In this research, we introduce an index measure that quantifies the spatial and temporal relation of production orders and investigate dynamic effects of production order interdependencies using real production feedback data and derive first results for the improvement of the prediction of logistics performance in an early production planning stage as well as for the configuration of production planning and control.

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Keywords: Production; Order; Interdependency; Granular; Matter

1. Introduction

Manufacturers are under the continuous pressure of driving down costs while being subjected to increasingly globalised market pressures to shorten production lead times and increase delivery reliability. Shortened product life cycles and an increasing demand for custom-made products further add to the complexity of effective planning and control of modern manufacturing systems. As a pivotal strategic activity, production planning in particular needs to be able to accurately predict especially customer-facing logistics key performance indicators, namely order lead times and due date deviations in the early and aggregate stages of production planning [1–3]. The ability to predict reliable estimates of logistics performance can align customer expectations and improve customer satisfaction while also improving the planning of company resources and operations, hence retain competitiveness [3]. However, companies frequently find themselves struggling to foresee and integrate operational dynamic effects related to production orders into production planning decisions [4,5]. Such unplanned dynamic effects may result from interdependencies between individual production orders on the shop floor and can include unplanned prioritisation, sequence deviations, order cancellations, and others [6]. While some causes for interdependencies are known, a general understanding of the dynamic effects on logistics performance has not explicitly been established. This study aims to introduce a new concept for quantifying dynamic effects in real production data towards the improvement of production planning.

The remainder of this paper is structured as follows: Section 2 provides a background to this study by focusing on previous approaches investigating dynamic interdependency effects in performance prediction. Section 3 and 4 outline the method applied in this study and Section 5 outlines the key results. A discussion of the results is given in Section 6 and the contribution is concluded in Section 7.

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2. Background

To predict logistics performance, it is common practice for manufacturers to use static production planning models whose primary aim it is to define production rates under given capacity constraints. In these models, the integration of aggregate and fine planning plays a key factor, which production planners often disregard due to complexity of this task. Literature on integrated production planning acknowledges that the lack of integration of dynamics on the lower-planning and the control level in strategic planning can lead to sub-optimal logistics performance [6–10]. Yet, the majority of integrated production planning literature uses static models which cannot address the dynamic components in the production planning decision. Methods from data mining provide alternative concepts for early prediction of logistics performance by using historical production data to analyse artefacts of dynamic effects. Such approaches primarily revolve around using order characteristics of foregone orders as improved predictors of logistics performance (c.f. [7–9]). While data mining approaches succeed at observing potential dynamic interdependency effects, they are lacking an underlying theory of investigation.

Different kinds of approaches from the field of granular particle systems are used to transfer analytical models from dynamic particle-to-particle interactions in order to explain the performance or state of a system. Granular matter systems consist of a large number of discrete particles which interact through short-distance mechanical contact within a defined system boundary [10] (see Figure 1, taken from [10]). Due to these system properties, granular particle observations have been successfully used to describe dynamic effects taking place in closely-related systems.

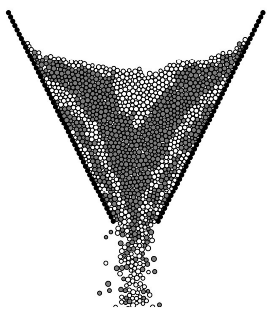

Fig. 1. A system of granular matter contained by a hopper with outflows.

The most notable use of parallels from such granular particle systems for the explanation of logistics performance in manufacturing research is the funnel model of logistics performance, which is based on a simile to a particle system with outflows [11] (see Figure 2, taken from [12]). The funnel model is used in manufacturing research to represent capacity units (work stations) and describes their throughput behaviour in terms of inputs, WIP, and outputs [12]. The funnel model has been widely researched and used to calculate logistics performance indicators in production planning, however it disregards the principle of particle interactions, which the

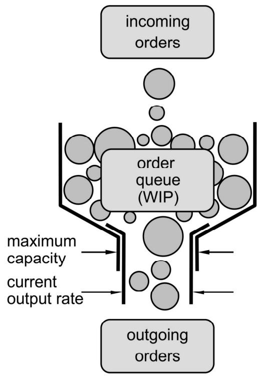

Fig. 2. The classic funnel model for logistics performance

original granular particle systems exhibit and which are in fact a key determinant for the system's state [10,13–15].
Other approaches from related disciplines have taken into account such dynamic particle interactions and transferred models, for example to production networks [15], whereby a unified analytical model was developed for describing material flows between production sites. Similar models were also researched in traffic systems [16,17], where the traffic flux was described in terms of a granular flux model and its interactions.

Applications of granular flow models such as the previous ones have shown to be successful in describing how interdependencies between individual entities contribute to the state of the system in closely-related disciplines. Yet, comparable applications in manufacturing research to study dynamic effects between production orders and the impact on logistics performance do not exist. Figure 3 visualises the concept of dynamic interdependencies between production orders in an extension to the classic funnel model.

This contribution hence uses insights from research on granular matter to explore such interdependency effects between production orders as a first step towards the improvement of the prediction of logistics performance and hence of production planning.

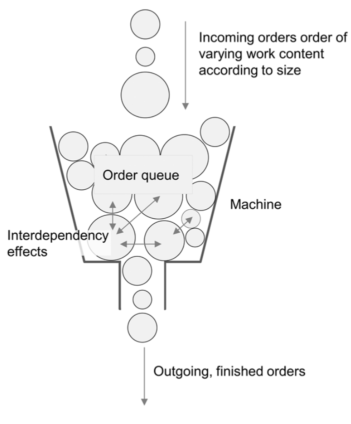

Fig. 3. An extension to the funnel model to account for dynamic interdependency effects as observed in granular matter systems