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Integrated Concept for Acquisition and Utilization of Production Feedback Data to Support Production Planning and Control in the Age of Digitalization

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Abstract

Digitalization is changing industrial production and is offering huge potential for producing companies. One effect resulting from the increasing presence of information and communication technology in production is the increasing quantity and quality of production feedback data. However, only collecting large amounts of data of data does not lead to high logistical performance and low logistical costs. It is essential to acquire the right data with as little operating expenses as possible, to analyze the acquired data target-oriented and to present the results user-oriented, so that concrete actions can be derived. In practice, this is a challenge for producing companies. To demonstrate the opportunities in this field of action, a concept was developed at the Institute of Production Systems and Logistics (IFA) (Hannover, Germany) and, furthermore, implemented in the IFA learning factory. This paper starts with a short introduction of the IFA learning factory. After that, the paper presents the developed concept in detail, describing the PPC system, the data acquisition using RFID, an order processing support system using ESL and the (real-time) data analysis. In the end a summarizing conclusion is given underlining the importance of an integrated concept for data acquisition and utilization.

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Keywords: Learning Factory; Digitalization; RFID; Feedback Data; Production Planning and Control

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1. Introduction

In order to meet high customer requirements, enterprises have to improve their processes continuously and do see digitalization as a solution approach [1]. Looking at producing companies one possibility to improve production planning and control (PPC) and at the end the logistical performance towards the customer is to record and evaluate feedback data in real-time and derive suitable measures [2]. Numerous preliminary works address the new possibilities of big data through cyber physical systems or approaches for data usage [2] [3]. Krüger et al. discuss the usage of information and communication technology in assembly lines and how network structures and control of the lines are affected [4] Mourtzis et al. present a monitoring system for shop floor control following the Internet-of-Things paradigm and using smart sensors resulting in a raise of the awareness on the status of manufacturing resources [5]. Frazzon et al. describe a data-driven adaptive planning and control approach that uses simulation-based optimization [6]. However, data integrity is still often insufficient in industrial practice [7]. In particular small and medium-sized companies are faced with the question, to what extent they have both the expertise and the financial leeway to invest in modern information and communication technology (hard- and software). To pick up on this point, an integrated concept was developed at the Institute of Production Systems and Logistics (IFA), which supports PPC on the basis of feedback data from production. In particular, work was done on data presentation and target-oriented information transport to the addressees. For validation and to transfer the key ideas and basic principles of the concept into practice by means of training courses, the concept was implemented in the IFA Learning Factory.

2. Fundamentals

Before presenting the developed concept, it is important to discuss the topics of production planning, production control and production monitoring in general. Fig. 1 gives an overview on operational tasks that have to be fulfilled by producing companies. The structuring of the tasks and the following description are based on the Hanoverian Supply Chain Model – a framework for PPC and supply chain management (www.hasupmo.education) [8].

In production planning, a distinction can be made between a long-term, a medium-term and a short-term planning level [8]. In long-term and medium-term production planning, fundamental decisions are made and measures with a long realization time are initiated. In short-term production planning, the focus is on creating a feasible production plan. Therefore, the tasks lot size planning, scheduling of production orders and capacity planning have to be done.

The aim of production control is to realize the previously prepared production plan as economically as possible despite unavoidable disruptions like the lack of staff or delayed deliveries [9]. As can be seen in Fig. 1 three tasks have to be fulfilled during production control: order release, sequencing at the workstations and capacity control [10]. The first task is the order release after which the orders are physically in production. At the workstations the orders are brought into a defined sequence for processing (e. g. FIFO, due date oriented or set-up oriented). Additionally the capacities are controlled (e. g. based on the backlog). Within the scope of production monitoring production feedback data is recorded. The actual situation determined in this way can be compared with target and planed values [8]. On this basis, the company can take actions. Possible actions cover an intervention regarding the flow of the orders through production, an improvement of the planning process or an optimization of supply chain design.

Production Planning	Production Control	Production Monitoring or Analytics
• Lot size planning	• Order release	• Acquisiton of production feedback data
• Scheduling	• Sequencing at the workstations	• Analysis of production feedback data
• Capacity planning	• Capacity control	• Deriving Actions

Fig. 1. Tasks to fulfil during production planning, production control and production monitoring [based on 8].

3. IFA Learning Factory

The IFA Learning Factory is an innovative and flexible training environment. It is used in university teaching as well as for the training of professionals and managers. The IFA Learning Factory immerses participants in an actual operational scenario with real manufacturing and assembly processes. This approach allows participants to experience production logistical interdependencies. An actual product, a metal model helicopter, is produced. The production process is divided into preproduction and assembly. In preproduction, the helicopter components, such as the rotor blades, are manufactured [11] [12]. In assembly the components are put together to complete the helicopter [13]. The following description focuses on preproduction [11] [12]. Its organization is based on the workshop principle. Seven different products with different work plans and routings are produced. In addition to the different processing times of the individual products, the order size also varies between 1 and 20 pieces. A PPC station is in place, which generates and releases the production orders based on the incoming customer orders. The workstations comprise two milling stations, a bending station, and a coating system, that represents a batching process. The employees on the workstations conduct the sequencing of the waiting production orders at the workstations based on defined rules. A logistician transports the raw material, the semi-finished products and the finished goods to dispatch via the workstations.

4. PPC system

A Microsoft Access© based PPC system has been programmed for the IFA Learning Factory. For each product, the work plans and target times are consigned in the system. Customer orders arrive on the basis of defined patterns. A routine converts customer orders into production orders. The system also performs scheduling and sets up due dates (start and end dates for each operation of the production orders). Additional routines exist to support the production control tasks order release and sequencing and for the processing of production feedback data.

5. Acquisition of production feedback data using RFID

In order to record production feedback data, RFID technology is deployed in the IFA Learning factory. RFID, which is an important AUTO-ID technology, is nowadays widespread and used in many companies. RFID technology eliminates the need for manual production feedback data collection. The resulting data from the shop floor is available in real time. In a case study presented by Zhong et al. [14] the implementation of a real time MES increased the output by 8 percent and reduced the WIP by 27 percent. In particular, the employees benefited in their daily work because of greater plan quality and fewer fire-fighting situations.

In the IFA Learning factory RFID technology is used to capture several time stamps and process them directly in the PPC system. A write event is triggered by the registration of a RFID tagged loading box, which is permanently linked to one production order during a production run. Therefore, the PDA terminals on every workstation were supplemented with a simple input routine, allowing a direct integration of the recorded timestamps in the PPC system.

Fig. 2 shows the operation specific throughput element [15]. The throughput element subdivides the throughput time at a workstation into different time periods. In total, five time segments are described, which can be divided into two higher-level classes. The first class, the inter-operation time, includes the time periods idle time post-processing, transport and idle time pre-processing. The second class, the operation time, can be subdivided into the components set-up and processing. The operation specific throughput element is defined in such a way that when operation at a workstation is finished, the throughput element ends and the subsequent idle time post-processing is assigned to the throughput element of the subsequent workstation.

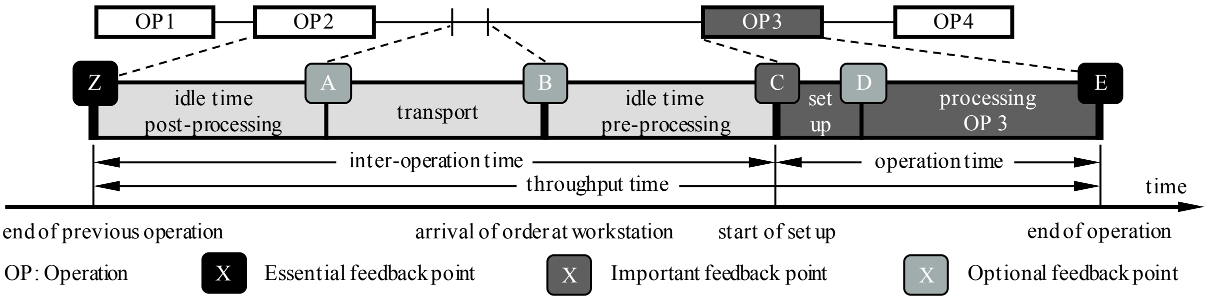

Fig. 2. Throughput Element with RFID feedback points realized in the IFA learning factory [15] [16].

The letters (A, B, C, D, E and Z) in Fig. 2 show the possible feedback points which can be recorded theoretically. Furthermore, the figure shows a subdivision of the defined feedback points into essential, important and optional feedback points. In the IFA learning factory, the essential feedback points (Z, E), the important feedback point (C) as well as feedback point (B) are implemented. Due to the mentioned definition of the throughput element, timestamp E (end of operation) is identical with timestamp Z (end of previous operation) of the following operation. In accordance with this, three feedback points are recorded by RFID technology for each operation in the IFA learning factory. Resulting, the idle time post-processing together with the transport time, the idle time pre-processing and the operation time can be distinguished. Depending on the requirements, the tracking of individual feedback points can also be deactivated.

6. Digital order execution support system using ESL

Fig. 3. Loading boxes with ESLs at front and back and RFID cards at both sides.

To support order execution on the shop floor, a system using ESL (electronic shelf labels) was developed [16]. Various data from the PPC system is brought to the shop floor via the ESL almost in real-time. The information provision is customized for each addressee and considers the progress of production. The digital order execution support system makes paper in production obsolete. The information provided is both static (e.g. order number) and dynamic (e.g. actual workstation). The concept helps to realize classic production control procedures (looking at the task sequencing e. g. FIFO or EDD) and, beyond that, enables the implementation of dynamic control procedures that aim on real-time optimization of logistical target achievement and use algorithms for this purpose (e. g. dynamic sequencing or dynamic routing). [16]

7. Traffic light system

There is also a technical support for the logistician in the form of a traffic light signal at each workstation. The traffic lights are connected to the PDA terminal and the PPC system. They change their colors depending on the system status respectively depending on new RFID scans at the feedback points described above. If the light blinks red, there is a new transportation order at the respective workstation. If the yellow light shines permanently, there are orders waiting for transport. In contrast, a green light indicates, that there are no waiting transportation orders. Due to the traffic light system, the logistician needs less time, before he notices new transportation orders, and can optimize the transportation paths. Thus, the idle-time post processing and the time for transport can be reduced.

8. (Real-time) Analysis of production feedback data

The production feedback data can be exported to Microsoft Excel© to perform evaluations. After an export of the data the logistical behavior of the entire production system and of each individual workstation can be evaluated via big data analyses [11]. Furthermore, enabled by the implementation of RFID technology, an app was developed to depict production in real-time (see Fig. 4). The app can be accessed on PCs, tablets and smartphones. This approach allows the data and evaluations to be used either in the office or directly on the shop floor, as required. Because of the app, production and order progress can be monitored in real-time. In addition, employees are enabled to make target-oriented control decisions. The current situation of each workstation and of the entire system can be supervised via the app. The production feedback data is evaluated in the form of key figures, throughput diagrams, lateness histograms and a throughput time analysis. The KPI overview makes it possible to capture the system status at a glance. For example, the app evaluates which workstation is currently processing an order and, in addition, how many orders with which work content are waiting in front of which workstation. The average throughput time and the average schedule deviation are also shown for each workstation. Besides, throughput diagrams [17] are used. A throughput diagram shows the incoming and outgoing production orders to or from a production area or each single workstation over time. Several key figures like the work in process (WIP) or the backlog can be derived easily. With the help of the throughput diagram the actual measured values can also be compared with the corresponding planned values. To observe the due date situation in and out of the system lateness histograms [17] are generated. These show frequency distributions of the schedule deviation. In this way, the mean value and the variance of the schedule deviation of the overall system and of each workstations is very well represented. The throughput time of production orders can be broken down into the elementary components described before due to the large number of feedback points at each workstation and the resulting high resolution of the data. With the app, a very precise throughput time analysis and, consequently, a target-oriented derivation of measures to reduce throughput time is possible. The app also enables a precise localization of each order in production. Statements on the throughput time so far and, by combining this information with information on the current backlog of the workstations, estimations of the remaining throughput time are possible for each order. If required, individual orders can be prioritized. In a special visualization the layout of the production site is included. This is particularly intuitive for the viewer. It does not necessarily include a static layout.

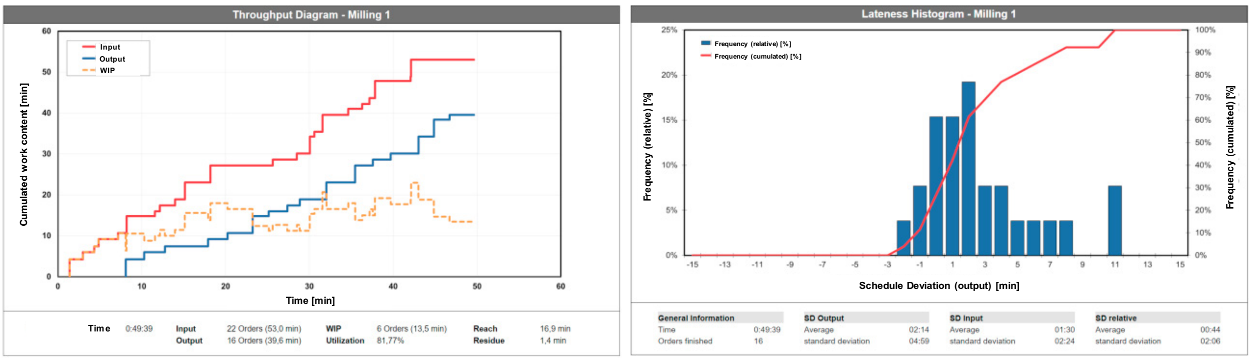

Fig.4. Extract of the app for real-time analysis of production feedback data (throughput diagram and lateness histogram).

9. Conclusion

By using recent technologies, the amount and quality of production feedback data can be improved and the data can be analyzed in real-time, both with small operational effort. It is a great challenge for producing companies to choose the right technologies and evaluations, so that the operative accomplishment of production planning and control is supported and processes and parameters of PPC can be improved.

This paper presents a concept using recent technologies and connecting them. The concept includes a lean PPC system, the acquisition of production feedback data via RFID, a user-oriented provision of the information on the shop floor via ESL and the real-time processing and visualization of the feedback data in an app. The concept was implemented and validated in a learning factory and is now used in trainings for students, specialists and managers.

The concept supports production planning and control respectively the individual PPC tasks in a variety of ways (see Table 1). The tasks of production planning are particularly supported by the presented data analysis. For example, deviations between the planned and actual times can be easily detected and the target times can be adjusted. Real-time data is not necessarily required to support planning tasks, but the high granularity of the data is a major advantage. For example, throughput times can be analyzed much better if not only the start and end times of an order are available as feedback data, but several time stamps have been recorded for each operation, as suggested in Fig. 2. The tasks of production control benefit in particular from the ESL. Errors are avoided, because, to name a few examples, orders are not released prematurely or the specifications for sequencing are met because the ESL of the next order to be processed is marked in color. Results are e.g. a lower WIP leading to lower throughput times and a higher sequencing discipline leading to a better schedule reliability. In addition, the ESLs enable the implementation of dynamic routing, which enables short-term load balancing. The live key figures and the live evaluations are also very helpful for production control, as there is always transparency regarding the current WIP and the current backlog. For example, order release can be postponed when there is a high WIP or the capacity can be adjusted when backlog builds up. The transport processes are supported by the traffic light system, the ESL and the high-resolution throughput time analysis.

Table 1. Support of the fulfilment of the PPC tasks

Task		Which elements of the concept support this task?
Production Planning	Scheduling	(real-time) feedback data analysis
	Capacity Planning	(real-time) feedback data analysis
Production Control	Order Release	ESL, real-time feedback data analysis
	Sequencing at the workstations	ESL, real-time-feedback data analysis
	Capacity Control	ESL, real-time feedback data analysis
Transport		traffic light system, ESL, (real-time) feedback data analysis

The design and validation process of the concept showed, that very expensive technologies do not necessarily bring the highest added value. It is much more important to first create a closed concept, what should be achieved using the technologies. The aim is to link the individual technologies in a meaningful way and to enable the exchange of data. Isolated solutions are to be avoided. Only on the basis of a closed concept the aimed improvement of the logistical objectives can be achieved. With the increased data availability made possible by recent technologies there is a risk of wanting to carry out too many and too complex production feedback data evaluations. This can lead to excessive demands on the user, who ultimately has to interpret the evaluations and derive decisions. User empowerment is a key enabler for the value-added use of recent technologies in production analytics. Easily understandable and yet particularly meaningful visualizations are beneficial. The feedback from participants of training courses shows that especially small and medium-sized companies are looking for such solutions based on integrated concepts.

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