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Information and decision-making delays in MRP, KANBAN, and CONWIP

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ABSTRACT

A production control system (PCS) can be considered an information-processing organization (IPO). The performance of different production control systems has been studied intensively. However, their decision-making efficiency has not drawn much attention. The amount of information in a production control system can lead to a delay in decision-making. This paper considers the effect of product position information on decision-making. We use information entropy to measure the amount of position information in products and find that there are different amounts of position information in MRP, KANBAN, and CONWIP. Then, we compare the decision-making time delay among the three production control systems across identical organizational structures for information processing. We conclude that the production control system with the smallest amount of information spends the least amount of time in decision-making.

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1. Introduction

Many studies have aimed to examine the production performance of the three production control systems (PCS) MRP, KANBAN, and CONWIP, e.g., Huang et al. (1998), Roderick et al. (1994), Pettersen and Segerstedt (2009), Krishnamurthy et al. (2004), and Takahashi and Myreshka (2005). Most researchers focus on how MRP, KANBAN, and CONWIP order release strategies influence their performance or efficiency. Concerning efficiency, for a given level of throughput, a MRP system will have more work in process (WIP) on average than an equivalent CONWIP system (Hopp and Spearman, 1996). However, there is less research regarding processing information and making decisions in production control systems.

An organization can be considered an information processing system (Galbraith, 1973, 1977). In a manufacturing system, the PCS is a system of processing information. The diversification and frequent changing of market demand make the acquisition and transmission of information in PCSs increasingly important. Every decision, from the master production schedule (MPS) to the occasional production adjustment aroused by market change, needs prompt, efficient and comprehensive information. The efficient acquisition and transmission of information is crucial to production control implementation.

There is a substantial amount of information in a PCS, some of which relates directly to production and includes material variety, products quantity, batch size, the number of workstations, and processing time on workstations. The research of Karp and Ronen (1992) showed that firms wanted to acquire production information as comprehensive as possible to (1) plan the production and supply of products, (2) monitor the production process, (3) identify point(s) on a production line where the process fails and take effective actions, (4) change some attributes of products during the production process if necessary, and (5) guarantee the quality of products.

Information in a PCS, such as production scheduling, customer demand, raw material stock, and the amount of WIP, changes quickly and frequently. The information must be acquired and transferred completely, accurately and quickly to guarantee regular production. A lack of information will lead to various problems and even interrupt the production process.

Galsworth (1997) defined two types of information deficiency in a PCS: detail information deficiency and position information deficiency. Detail information covers issues regarding “what”, “who”, “when”, “how”, and “how many” related to a production procedure. It describes the details of manufacturing and service as well as the production mode, including procedure standards (operational standards and methods) and technical requirements (size and tolerance errors). Position information responds to questions about “where the manufacturing occurs”. The production process may stop or even be unable to start without position information. Although most pauses

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aroused by a lack of position information in a production process seem to be trifles (i.e., only last for less than 1 min), such pauses may take place hundreds of times in one working day. Thus, position information deficiency affects the production rate and yield rate, producing a significant operational obstacle. A lack of accurate and complete information results in serious trouble: instead of preventing problems, firms have to settle problems after their appearance. Operators have to spend time to search, wait, check and settle.

More information leads to higher accuracy; however, the acquisition, transmission, and process of more information needs more manpower, more materials or more financial resources. In other words, increased cost is incurred to obtain more information. At the same time, more information results in delayed decision-making, which definitely increases the time cost. There has been extensive literature examining how to make decisions more accurate; however, much less research has been concerned with how to shorten the decision-making time. The amount of information makes a strong impact on decision-making time as well as other resources and should be kept as small as possible without the loss of a certain accuracy of decisions. Shannon (1948) defined information as the uncertain description of the existence and development/movement of events/objects and built a model to measure information based on the concept of entropy in statistical thermodynamics. The more uncertainty there is in a PCS, the higher the information entropy. Therefore, uncertainty should be reduced in any PCS (Gong et al., 2009). With the development of information theory, the connotation and application of information entropy has been largely expanded with the basic principles unchanged. Yao (1985) and Yao and Pei (1990) used entropy theory to study the flexibility of arranging procedures in agile manufacturing systems. Karp and Ronen (1992) and Ronen and Karp (1994) explored the method to calculate the amount of information needed to confirm the positions of products in a production line. In the field of operation management, information entropy is usually used to describe the complexity of a PCS. Deshmukh (1993), Deshmukh et al. (1998) built a framework to evaluate the static complexity of a PCS based on information entropy. Frizelle (1995) and Frizelle and Woodcock (1995) defined two types of complexity in PCSs using the idea of entropy: structural complexity and operational complexity. Calinescu et al. (2000) reviewed the literature that used information entropy to measure the complexity of PCSs.

Radner (1993) regarded a firm as a computer and appropriated certain concepts from computer science to formulate the definition of the "special computer" and found that the time to make decisions was related to the amount of information. Radner (1993) proved that the time delay to make decisions is $D \geq 1+\log_2 N$, where N is the number of information items. The hierarchical network examined in Radner (1993) has been applied into a variety of fields. In this paper, we adopt the idea from Radner (1993) that a PCS operates like a computer: receiving information, processing it, and exporting the final results (the decisions). A manager or an operator is a processor, and the time for information processing is the delay. We call the hierarchy the IPO, or information processing organization, and adopt the convention that the lowest rank in the IPO is level one. In recent years, much attention has been devoted to the topic of supply chain visibility in specific information flows, such as order status, inventory level, delivery plan, etc. (Caridi et al., 2014). Radio-frequency identification (RFID) enables item-level information visibility and instantaneous tracking/tracing ability (Zhou and Piramuthu, 2013). For example, using an RFID system, a maintenance company can eliminate inaccuracy problems related to inventory recording delays brought about by mishandling in the component repair process (Ngai et al., 2014). Although RFID technology has been regarded as a promising solution for inventory inaccuracy, whether the retailer deploys RFID depends on the relative value of the available rate of ordering quantity and RFID read rate improvement (Fan et al., 2014). RFID technology can be used to collect real-time production data to provide timely and effective solutions by an intelligent and real-time multi-objective decision-making model (Wong et al., 2014). In sum, RFID can make a firm an information processing organization. Today's supply chain professionals are inundated with data, motivating new ways of thinking about how data are produced, organized, and analyzed. RFID can produce a substantial amount of data. This data production has provided an impetus for organizations to adopt and perfect data analytic functions (e.g., data science, predictive analytics, and big data) to enhance supply chain processes and, ultimately, performance (Hazen et al., 2014).

In this paper, we will focus our research on three aims: (1) to quantify and measure information, (2) to compare the information amounts in MRP, KANBAN, and CONWIP, and (3) to study how the information amount affects the decision-making delay in the three production control systems. The paper proceeds as follows. Section 2 presents an information entropy model to measure the amount of position information of products and identifies the relationship between the batch size and the amount of position information. Using information entropy, Section 3 describes a comparative study of the information amounts in MRP, KANBAN, and CONWIP. Given the identical organizational structure for information processing, the different decision-making time delays in MRP, KANBAN, and CONWIP are carefully examined in Section 4. Section 5 concludes.

2. Information entropy: Measurement for product position information

In information theory, the amount of information is a physical quantity that quantitatively measures the information transferred when an event happens with a certain probability. The probability of an event has much to do with the amount of information involved in the event. In other words, decreased probability correlates to more information, which implies increased uncertainty. If an event is certain to happen (it has a probability of 1), the amount of information involved in the event will be 0 (no uncertainty). If an event will never happen (it has a probability of 0), the amount of information involved in the event will also be 0. The concept of entropy has been integrated into information theory to measure the uncertainty of a stochastic event. Given a stochastic event $E=\{e_1,\ldots,e_n\}$, its probabilities of occurrence are $P=\{p_1,\ldots,p_n\}$, satisfying $0 \leq p_i \leq 1 (i=1,2,\ldots,n)$ and $\sum_{i=1}^{n} p=1$. To measure the probability of the stochastic event E, the entropy function is

$$H=-K\sum_{i=1}^{n}(p_i \log p_i), \tag{2.1}$$

where K is a positive constant. For simplification without loss of generality, we set $K=1$. We also set $0 \log 0=0$.

H is called information entropy or Shannon entropy, showing the amount of information needed to eliminate uncertainty. Information entropy has the following properties:

(1) Non-negative: $H \geq 0$
(2) Symmetry: H remains the same whenever the order of p_i is changed
(3) Extremum: Given n, H is a maximum and equal to $\log n$ when all of the p_i $(i=1,2,\ldots,n)$ (i.e., $1/n$) are equal ($H_S^{\max}=\log n$).

Now, we measure the product position-information in a PCS using information entropy. Consider a production line containing

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