EVALUATION OF RFID FOR INFORMATION VISIBILITY BASED JOB-SHOP SCHEDULING

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ABSTRACT

This study presents an RFID-based traceability approach to improve production scheduling. We propose a novel information visibility-based scheduling (VBS) rule that utilizes information generated from the real-time traceability systems for tracking work in processes (WIPs), parts, and components to adjust production schedules. We then evaluate the performance of this information visibility-based schedule against the classical scheduling rules. The results of the simulation suggest that RFID-based scheduling rule generates better performance compared to traditional scheduling rules with regard to cycle time, machine utilizations, backlogs, and penalty costs.

Keywords: RFID; Manufacturing; Traceability; job-shop, scheduling

INTRODUCTION

In most manufacturing situations, physical and information flow of products from the raw materials, parts, components, and work-in-processes (WIPs) to the end products can become quite complex. Without full information on any delays or interruptions in the production processes, companies face the issues of ineffective production planning, scheduling, and control, missing items, low product quality, or high defect level. Many automatic identification technologies (AITs) such as Radio Frequency Identification (RFID) offer the track and trace capabilities. RFID is built around the idea that, to search for things without too much time and trouble, one can simply put radio transceiver tags on physical objects; the tags can then be used to find those objects (Brazeal, 2009; Brown, 2007). RFID has been used extensively in improving business performance in warehouse and distribution centers, logistics, and inventory management across the supply chain. Furthermore, the trend toward implementing RFID in other areas such as a hospital or manufacturing processes is increasing (Gunther, Kletti, & Kubach, 2008; Hunt, 2007; Jones, 2008).

A majority of literature on RFID is supply chain oriented, focusing on tracking items as they move through the operations channels. Only a few studies consider the potential of RFID-improved track and traceability in manufacturing operations such as job shop or assembly line improvement, quality inspection, or work-in-process (WIP) monitoring. In exploring this potential of RFID in manufacturing, the question arises, under what conditions information visibility-enabled track and traceability improve manufacturing performance and how? To answer this research question, this study focuses on job shop production scheduling perspectives.
Scheduling tasks are very important to meet customer demands by optimizing time, productivity, defect level, product quality, and cost. Thus, the goal of this study is to examine how track and traceability through RFID can facilitate job shop production scheduling activities and under what settings such information visibility can add value to an organization.

After describing the related literature in the next section, we propose a novel information visibility-based scheduling (VBS) rule that utilizes information generated from the real-time traceability systems for tracking work in processes (WIPs), parts and components, and raw materials to adjust production schedules. Our evaluation and justification of RFID deployment is based on real manufacturing process data. We conclude the paper with a discussion on how RFID can enable track and traceability to improve production scheduling performance.

**BRIEF LITERATURE REVIEW**

Scheduling has been defined in different ways. Stevenson (2007, p.721) defines scheduling as “establishing the timing of the use of equipment, facilities, and human activities in an organization.” Heizer and Render (2006, p. 518) refer to aggregate scheduling as “determining the quantity and timing of production for the intermediate future … with the objective of minimizing cost over the planning period.” In the job shop environment, scheduling refers to a set of activities in the shop that transform inputs, a set of requirements, to outputs, products to meet those requirements (Nahmias, 2004, p. 403). In a manufacturing facility, Hermann (2006) defines production scheduling systems as a dynamic network of persons who share information about the manufacturing facility and collaborate to make decisions about which jobs should be done when. Several studies have explored the use of RFID to facilitate and improve production scheduling. Shibata et al. (2006) introduce RFID technology at production sites through “the Production Process Monitoring Solution” in order to visualize the production process in the production line in real time and to support the efficient operational improvement and the utilization of data collected by RFID. Huang et al (2007) propose the RFID-based approach to improve the real time shop-floor information visibility and traceability at a walking-worker fixed-position flexible assembly line. Zhou et al (2007) develop the RFID-based remote monitoring system for internal production management. Accordingly, the flow of raw materials, work in processes, finished products, and information is transparent through the central monitoring system. Huang et al (2008) present RFID-based wireless manufacturing approach to improve shop-floor performance. They describe how RFID can manage work in process (WIP) inventories in job shop environment, which normally suffers from a bottleneck of capturing and collection of real-time information. Liu and Chen (2009) apply RFID technology to improve production efficiency at an IC packaging house. The study indicates that RFID can reduce the operating time, eliminate data processing errors, eliminate clients’ complaints and penalties, reduce operator’s workload, and increase productivity. However, to our knowledge, no study has focused on how track and traceability through RFID can help in achieving better job shop scheduling, especially in facilitating dynamic scheduling activities in shop-floor operations. Although these studies point out the importance of tracking WIPs or finished products in real time in the operations and illustrate the value of location information to facilitate scheduling activities, they have not proposed and evaluated how RFID can facilitate rescheduling tasks or update an existing plan when disruption situations or unexpected events occur in the shop-floor
operations. Thus, our study aims to partly address this gap by proposing a traceability-based information visibility model and investigating how an RFID-based scheduling rule can facilitate job-shop scheduling activities.

PROPOSED VISIBILITY-BASED SCHEDULING (VBS) RULE

Job-shop scheduling activities are viewed as a decision making process, involving and requiring interaction with many functions in an enterprise. Most of the scheduling input data such as production plans, master schedules, capacity planning, or resource allocation are prepared at a higher planning level (e.g. ERP system) before the detailed scheduling tasks begin. Orders released to the shop floor are determined based on inventory levels, demand forecasts, and resource requirements. Accordingly, production planners prepare an operational schedule and release it to the shop floor. The most important scheduling task is to determine which jobs should be done and when these jobs should begin and end. The information is used (i) to prioritize jobs for production, (ii) to sequence production tasks, and (iii) to assign and reassign manufacturing resources such as people, equipment, raw materials, tooling, or production lines (Pinedo, 2009).

Figure 1 presents a real time track and traceability-based scheduling rule that utilizes improved information visibility from RFID. RFID is deployed at the shop floor level to provide a unique identification to every work-in-process (WIP) along with major parts and components throughout the production line. This means that the production planners can immediately identify, locate, and appropriately address all work orders/units in the facility. The gap between physical and information flow of the work orders is reduced and, consequently, the planners know exactly which units are being worked on. As presented in Figure 1, the visibility-based scheduling (VBS) rule begins when the planners release work orders to the shop floor operations based on actual customer demand as well as demand forecasts (A). Usually, there are multiple products or different product families processed in the shop-floor operations. The planners are also able to determine whether the raw materials are available for the production run (B) and determine both utilized and available capacity at each workstation (C). If there are rush jobs waiting at the operating workstation (D), the priority is then set to those jobs first (E). Any changes to the jobs due to material shortage or machine failures are reported in a timely manner (F). The planners can reschedule the current plan and set the highest priority to the product family that has the highest penalty cost per backlog (G). With RFID, the planners are also able to determine the total quantity of WIPs for each product family waiting and being processed at the next workstation (H and I). This information visibility leads to significantly improved operational flow, especially when each product family may require different production procedures or require significant set-up time for material and machine preparation. If the incoming WIPs at the current workstation are from the same product group that are mostly processed at the next workstation, the priority can be set to those groups to increase the flow of the production run (J). Likewise, if the incoming WIPs are from the same product group as being run on the machine currently (K), the priority is set to those groups to reduce setup time (L). Otherwise, an operator at the workstation can select the unprocessed units that have the longest waiting time (N) or select units using the traditional scheduling rules (O) such as earliest due date (EDD).
Figure 1: Visibility-Based Scheduling (VBS) Rule
With RFID, the planners can keep track of when the WIPs actually arrive or leave specific workstations and can determine the exact time WIPs actually stay at each workstation. This information is very helpful to the scheduling tasks. If the average processing time of the selected WIPs is longer than historical data (P), the planners can stop the production on that product family, conduct a root cause analysis, and select other units instead (R). RFID also allows tracking the rework or failed WIPs for each product family in real time. If the percentage of reworked units is greater than the predetermined threshold, proper corrective action can be made to avoid unnecessarily utilizing the current shop-floor resource capacity (R).

AN IMPLICATION OF VISIBILITY BASED SCHEDULING (VBS) RULE

An in-depth study of an RFID deployment assessment at one of the production lines from XYZ Company (name disguised) is conducted to explore the benefits of an RFID-based traceability system. XYZ Company is a manufacturing services provider of complex optical and electromechanical components. The company is considering implementing RFID on a production line of the optical receiver-transceiver, called OPT, used in telecommunication networks. Although the case presented in this study is for a specific job shop, it does provide details of logical process flows and problem scenarios that normally occur in manufacturing operations. A logical flow of OPT manufacturing processes is presented in Figure 2.

![Figure 2: A Logical Flow of OPT Manufacturing Processes](image)

This production line manufactures about 87 different products but can be grouped into four major product families. Operating on a quarterly timeframe, the facility receives weekly forecasts from its customer-supplier development program at the beginning of the quarter. To utilize its capacity and to avoid overtime at the end of the quarter, orders are released at the beginning of the week based on both confirmed purchase orders and demand forecasts. Priority
is given to the released production orders that represent actual purchase orders from customers. The shop-floor currently relies on a barcode system and assumes that all operators follow the established operating procedures by scanning all WIPs before and after WIPs are transferred from one workstation to another. WIP totes are currently assigned to the sub-workstation based on the judgment of authorized test engineers. Usually, the Earliest Due Date (EDD) scheduling rule is utilized to assign the priority to the jobs with the earliest due date first with the objective of minimizing lateness. If work orders released have the same due date, First In First Out (FIFO) is used to set the priority to the waiting jobs that arrive at the queue first in order to minimize the variation in the waiting times of the operation. In some circumstances, the Service in Random Order (SIRO) is used when no priority is given to the waiting jobs and the next job is selected randomly.

In this study, a simulation approach is applied to examine the benefit of information visibility-based scheduling (VBS) rule that utilizes the real-time traceability systems. We create a simulation model for the job-shop OPT manufacturing facility using the Simio simulation program. SimioTM, version 4.0, is a simulation modeling framework software package based on intelligent objects (Pegden, 2007). The purpose of our simulation model is to test the performance of information visibility-based schedule (as presented in Figure 1) against the classical scheduling rules. Although there are several ways to carry out dispatching for the planning and scheduling decisions, we only compare the VBS rule against two different dispatching rules: FIFO and EDD for the model comparison.

The simulation results show that the average cycle time for all product families is reported at 51.81 hours for FIFO, 54.78 hours for EDD, and 46.59 hours for RFID. When RFID is in use, the average cycle time improvement over FIFO and EDD for all product families is at 10% and 15%, respectively. As expected, a decrease in the average cycle time results in a decrease in backlogs. With an average quarterly demand of 4,045 units for all product families, total backlog orders in the case of FIFO, EDD, and RFID scheduling rules are 697, 748, and 560 units respectively. Clearly, RFID helps in reducing backlogs as opposed to the traditional scheduling rules (20% improvement over FIFO rule and 25% for EDD). These results are reasonable. With RFID, the facility can keep track of the flow of WIPs at each workstation and make better scheduling decisions using the scheduling approach described in Figure 1. Information visibility enables production planners to effectively and efficiently determine the quantity and timing of production for each product family at each workstation. At the shop-floor level, the testing engineer at W_4, for instance (see Figure 2), knows the exact quantity of each product family in the waiting area and in the assembly workstation (W_3). Thus, priority is set to those with the highest quantity to reduce the setup time and to smooth the production flow. Accordingly, the set-up time and testing time at performance testing (W_4) workstations decrease dramatically. The average time spent in machine setup for EDD and FIFO rule is reported at 13.93 and 12.35 minutes. However the average time for setup gets better with RFID at 8.89 minutes, approximately 28% improvement over FIFO and 36% improvement over EDD. Without information visibility as in FIFO or EDD rules, shop-floor operators may continue working on a particular model without realizing that the weekly shipment requirement of that model has been met or shop-floor resources such as the labor and machines at W_3 and W_4 are not available for that model. As a result, the average cycle time and backlogs may increase.

References are available upon request from jong.chongwatpol@okstate.edu.