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An RFID application in large job shop remanufacturing operations

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ABSTRACT

In this study, we evaluate the use of radio-frequency identification (RFID) technology for improving remanufacturing efficiency. We report the results of discrete-event simulation model that analyzes how RFID creates value within the remanufacturing operation. We find that the simulated gains from using RFID are quite modest, and propose alternative justifications for the major benefits seen in practice. We then provide a framework for deciding on the adoption of active RFID technology such as real-time location system (RTLS) for easy identification of components in the remanufacturing process and the adoption of passive RFID for permanently tagging components of remanufacturable products.

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1. Introduction

In this paper, we study how radio-frequency identification (RFID) technology, including active RFID technology such as real-time location system (RTLS), may generate value in remanufacturing operations. The US Department of Defense (DoD) has capabilities in 19 depots across the US that are able to remanufacture aeronautical, automotive and naval equipment, in addition to a variety of electronic instruments (DoD, 2003). The timing for this study is opportune for two main reasons. First, the DoD's demand for remanufacturing operations continues to grow with the intensive, long-term operational demands placed on its equipment in Iraq and Afghanistan. This increased level of demand places a premium on the optimal use of remanufacturing facilities and personnel available in the DoD system. Second, RFID technology continues to evolve at a rapid pace, so understanding its benefits will help in decision-making regarding investments in this technology. With RFID technology becoming more widely integrated within the DoD infrastructure, it is the right time to analyze its effectiveness. Our study discusses the implementation of real-time location systems at the Tobyhanna Army Depot in Pennsylvania as a means to improve its remanufacturing performance. Our objective is to identify the impact of the technology on process control, and what process characteristics make the technology most valuable. Finally, we propose a qualitative framework that helps identifying the conditions under which RFID should be used in a remanufacturing job shop.

This study proceeds with a quick overview of some related work on remanufacturing in Section 2 and on the use of RFID in production environments in Section 3. Then we provide a concise appraisal of what has been learned in past studies of RTLS in a remanufacturing operation in the DoD in Section 4, which sets the scene for the rest of the paper. Section 5 reports the results of a discrete-event simulation model to analyze the narrower issue of how RTLS creates value in the remanufacturing shop through reductions in flow-times. Our results suggest that the direct gains are relatively modest, compared to the overall gains found in other studies. In Section 6 we discuss the process of selecting specific RFID technology in a remanufacturing environment and the alternative choice of directly tagging components with passive RFID at the beginning of their service life rather than at the remanufacturing facility. We argue that this choice is largely driven by the feasibility of passive tagging and the value of information gained through monitoring the tag during its entire service life. The article closes with a conclusion, implications for practitioners and suggestions for future research.

2. The remanufacturing shop

Remanufacturing provides the basis for product recovery and re-use in supply chains. It focuses on value added recovery, rather than just materials recovery (recycling). It differs from repair operations because the product is typically completely disassembled, and all parts are inspected and returned to like-new condition before re-assembly.

There is substantial literature on remanufacturing dealing with tactical, operational and strategic questions. Several authors have argued that current manufacturing technologies, practices and

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processes can and should be used in support of remanufacturing operations (Ferrer and Whybark, 2000; Giuntini and Gaudette, 2003). Thus, in many ways, remanufacturing has the same broad goals as manufacturing including quality, speed, flexibility and cost. Therefore, the transfer of relevant best practices from manufacturing to remanufacturing is an important concern of many managers.

Also, many authors see remanufacturing as a process of growing importance in the overall product lifecycle. There are several reasons for this, including product take-back laws that mandate that manufacturers bear the burden of disposal at the end of a product's useful life (Mangun and Thurston, 2002), and the profitability/cost-effectiveness of remanufacturing durable products. In short, remanufacturing may make good business sense, with producers extracting benefits that offset some of the costs of take-back policies instituted in various countries. The key point is that, in every organization, it is useful to conceptualize remanufacturing as a profit-enhancing or cost-reduction activity.

A third point is that remanufacturing may often include the incorporation of component upgrades to add new features to the product or to improve compatibility with newer systems (Ayres et al., 1997). This point is particularly important for the DoD, which is frequently engaged in refreshing its hardware stock with new technologies. Excellent examples are found in the US Army's Bradley and Abraham armored vehicles upgrade program, the US Marine Corps' Harrier upgrade program, periodic updates of the US Navy's aircraft carrier fleet, and numerous examples in the US Air Force (including those involving the B52 Stratofortress bomber and the KC135 Stratotanker tanker, which were originally designed and built in the 1950s). The authors know of no formal models justifying the upgrade decision – including time and extent of repair – and note that this topic clearly warrants further study in the military context.

In the context of job shop operations, the remanufacturing literature remains limited. The main difficulty in this research stream is to model the job shop in a meaningful, generalized way. Guide, Srivastava and Kraus studied regular and expedited schedule, inventory buffer and capacity planning in simulated remanufacturing scenarios based on Air Force aviation depots (Guide et al., 1997a, 1997b). These studies generally recommended best approaches to schedule the disassembly–repair–reassembly sequence considering the uncertainty of the process. Since then, although much has been studied about high volume remanufacturing operations, but very little work has been done to understand the remanufacturing job shop.

3. RFID technology in production processes

In its simplest classification, radio-frequency identification (RFID) tags can be separated in two types: passive (where the tags do not have its own source of energy) or active (where the tag has a battery). The absence of battery allows passive tags to be smaller, simpler, and less expensive, which makes it a natural upgrade from barcode, with the benefit of carrying more information about the tagged item. Active tags, however, are bulkier and more expensive. The active design is generally selected when other tag capabilities are desired, in addition to item identification (Landt, 2001; Lahiri, 2005; Ngai et al., 2008). One particular type of active RFID tag is the real-time location system (RTLS).

Real-Time Location System (RTLS) is a special-purpose active RFID technology that is used to locate an object or a person within a pre-defined area. In its basic structure, three or more RFID readers (strategically distributed in the area of interest) sense the tags in the area and, by triangulation, indicate their location on a computer screen. It has been used in a variety of contexts to locate individuals, such as in amusement parks and in prisons (Ferrer et al., 2010). RTLS has been used in ports to facilitate the location of a specific container among thousands, and at automobile distribution centers to help finding a specific vehicle in the lot (Armanino, 2005). Its use in manufacturing sites has helped locating individually tagged items that may be lost in a large job shop (Miertschin and Forrest, 2005; Phelps and Rottenborn, 2006).

There is a substantial literature on the implementation of RFID to manage manufacturing operations. Concerns include the management of machine-paced processes (Wang et al., 2008; Vlad et al., 2009), shop floor control (Hozak and Collier, 2008, Thiesse and Fleisch, 2008), reverse logistics (Kärkkäinen, 2003; Karaer and Lee, 2007; Kulkarni et al., 2007; Sameer et al., 2009), integration with ERP or similar legacy systems (Kohn et al., 2005; Günther et al., 2008) and inventory accuracy (Fleisch and Tellkamp, 2005; Doerr et al., 2006; De Kok et al., 2008; Rekik et al., 2008, 2009; Szmerekovsky and Zhang, 2008; Uçkun et al., 2008).

Hozak and Collier modeled the use of RFID as a tracking device and as an enabler of lot splitting in first-time manufacturing. For a benchmark of performance, they used the performance of the facility when lots were labeled with barcodes. They developed an experimental design varying four factors: the transfer lot tracking mechanism (where RFID was one of three possible levels), the number of transfer lots using lot splitting (five levels), the job dispatching rule (first-come first-served, shortest processing times, and earliest due date), and the setup to run time ratio (three levels). Two performance measures were considered: mean flow time and proportion of jobs tardy. Analysis of variance was used to evaluate the performance improvement that could be attributed to RFID in this simulation, and to indicate under what scenario this contribution was more significant. In the direct comparison between barcodes and RFID, the authors found that the performance improvement was negligible with large lots, but they observed a significant impact from RFID when each batch was split into very small lots (Hozak and Collier, 2008). In a follow-up, they modeled the impact of imperfect information collected from RFID in lot-splitting manufacturing environments (Hozak and Hill, 2010).

Thiesse and Fleisch (2008) examined the use of RTLS to provide information on the location of physical items in a semiconductor fabrication facility, and the use of that information to generate efficient job schedules. They developed a simulation model of the manufacturing process incorporating RTLS-enabled dispatching rules, and found substantial benefits in terms of process speed achieved through improved efficiency gained by the new level of process visibility.

In some circumstances, permanent tagging may generate valuable information for the pre-remanufacturing process of disassembling components. Two articles have recently discussed the value of component information prior to disassembly (Kulkarni et al., 2007; Zikopoulos and Tagaras, 2008). Their analyses suggest that, since there is a high level of uncertainty about the quality of components entering the remanufacturing process, RFID-derived information can help sort components wherever it provides an alternative to manual inspection. Information about the history of the component might help lower costs in the remanufacturing process. Based on our experience, and confirmed by the findings in both studies, we notice that:

- The value of information from tracking components increases with potential variability in component quality. If variability is high, then information on component history has more value, which favors tagging. This may be true for parts that are sensitive to maintenance quality or use/abuse/environmental factors. (For example, officers at North Island Naval Air Station told us that FA-18 aircraft entering the remanufacturing process