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Developing a rapid response production system for aircraft manufacturing

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ABSTRACT

In this paper, the modeling methodology of rapid response production systems (RRPS) is proposed, and a case study in an aircraft manufacturing company has been developed to illustrate the application of the methodology. A new RRPS model has been proposed, and 12 components included in the model are alarming system of abnormal events, rapid response service station, coordination processing center, evaluation management, problem management, response visualization platform, unified graphic user interface, database, knowledge base, rapid response team, operation procedure standards (OPS), and rapid response training. The developed RRPS has been illustrated and implemented in Shanghai Aircraft Manufacturing Company (SAMC); the test has shown that the proposed methodology and the corresponding RRPS model has improved the capability of rapid response to changes and reduced the economic losses caused by abnormal events. Besides, the discussion and analysis has suggested that the developed RRPS has the distinguishing characteristics of agility, integration, robustness, and leanness.

1. Introduction

Responsiveness to abnormal events is a critical capability to production systems (Jiuh-Biing, 2007; Jan et al., 2010; Wang et al., 2007). The level of responsiveness relates to the scale and complexity of a system, which can be described by the number of parts or components in system and the number of machines and other assistive tools in shop floors; the level of responsiveness also relates to the abilities of manpower as well as the efficiency of planning and scheduling. As an indirect measure, the responsiveness can be reflected by the productivity of system, i.e., the utilization rates of machines and workers (Pedro et al., 2009). *Rapid response system* concept was proposed to enhance the responsiveness of system (Bradford and Eliseo, 2007). With the increased complexity, uncertainties, changes, and the distributed nature of modern manufacturing companies (Bi et al., 2007, 2008; Bi, 2011; Zhang et al., 2011; Xu, 2011a,b; Yin et al., 2012a), the responsiveness becomes more and more important to the operation of system (Samer and Yan, 2006). In manufacturing area, an alternative terminology of responsiveness is *agility*. Many enabling technologies, including reconfigurable systems (Bruccoleri et al., 2006) and agile supply chain (Baker, 2008), have been proposed to implement agile systems with the capability of quick responses to changes (Elkins et al., 2004).

Companies in aerospace manufacturing are generally large-scale and have very complex production and assembly processes (Liu and Wang, 2012; Xu et al., 2012b; Wang and Xu, 2008). Development of new aircraft products implies huge investments. For examples, the development cost for A380 is $9–10 billion (Castagne et al., 2009). In these companies, one of the challenging tasks in planning and scheduling of manufacturing processes is to deal with unanticipated job delays, it is not uncommon that the aircraft products cannot be completed and delivered to customers in time; in particular, job delays in production have been the serious issues to some Chinese aerospace manufacturing companies. Job delays may be caused by various changes such as shortages of raw materials or labors, breakdowns of machines or tools, quality problems identified from inspection and tests, changes of process plans, and mistakes in operations. Kilpi et al. (2009) indicated the importance of cooperative strategies to deal with the repairing services of aircraft components and identified the key factors related to the emergence of a particular cooperative strategy. When job delays cannot be dealt with appropriately within the company, product quality cannot be effectively assured and the customer satisfaction can be affected (Li and Warfield, 2011). Currently, many delays are not promptly solved due to the lack of rapid response systems and effective collaborative mechanisms (Pedro et al., 2009). Therefore, developing an effective rapid response system is an emerging research topic to enhance the responsiveness of aerospace manufacturing companies.

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Although numerous studies have been conducted on rapid response systems (Shan et al., 2012a,b; Xie et al., 2011, 2012; Xu et al., 2012c), the issues of job delays discussed above have not been thoroughly examined. The goal of this study is to propose a modeling methodology for *rapid response production system* (RRPS), and verify the performance of the developed model through a case study of the application in one Chinese aircraft manufacturing company. The design objectives of such a RRPS model are responsiveness, leanness, and seamless information integration to deal with uncertainties and changes. Firstly, the consideration of responsiveness of a RRPS is the primary objective to aerospace manufacturing enterprises. Responsiveness is the system ability to take prompt actions to address abnormal events or unanticipated changes when they occur. The RRPS should be designed to provide the infrastructure to response abnormal events with an enhanced system performance. Secondly, a RRPS should also be a type of emergency response system (Peng et al., 2011), which is capable of dealing with the urgency and avoiding the losses of production functions. Thirdly, the capabilities of rapid response must be achieved with the minimized additional resources; in other words, the performances of leanness and responsiveness must be considered simultaneously. *Leanness* means that the manufacturing system has the minimized wastes (Shahram, 2008). Note that the waste includes anything other than the essential and minimized equipment, materials, parts, and operation time in production. The sources of waste can be one of the following seven types: machining processes, waiting times, unnecessary transportation, inventory, no-value-added processes, motion, and product defects. One goal of the RRPS is to reduce the varieties of wastes. Fourthly, a RRPS is also about the seamless integration of enterprise information system so that system resources can be coordinated and optimized at all the levels of planning and scheduling the system. In the development of an emergency response information system, one should consider not only available technologies but also how a system is developed to meet requirements (Yoon et al., 2008). In addition, a RRPS should also consider the customer's satisfaction level, and a system for the service management will be an appropriate means to enhance customer's satisfaction. To this end, an Information Technology Infrastructure Library (ITIL) includes a collection of the best practices for IT service management, and the RRPS model is designed based on the guidelines from this collection. Finally, the proposed RRPS model must meet the requirements of the aforementioned aspects.

To validate the proposed model, a case study of the application has been developed in a Chinese aerospace manufacturing company. The application has demonstrated that the RRPS model has provided the prompt support to respond the abnormal events rapidly in the production system. In this paper, our work on a new RRPS model and the development of case study application has been reported. *Firstly*, existing literature on rapid response systems has been reviewed to identify the most critical requirements of a RRPS and some significant issues yet addressed. *Secondly*, the modeling methodology for RRPSs has been proposed from the perspectives of emergency response service and lean production components. *Thirdly*, a conceptual RRPS model has been developed based on the best practices described in the ITIL. The rest of the paper is organized as follows. In Section 2, a summary of literature review with the identified limitations has been provided; in Section 3, the modeling methodology is presented; in Section 4, a new RRPS model has been presented; the main components, functions and their relations have been introduced; in Section 5, a case study application in an aerospace manufacturing company is provided to show the effectiveness of the proposed model; finally in Section 6, the conclusions and discussions of future works are presented.

2. Literature review

Numerous literatures are available on agility, adaptability, responsiveness of production systems; readers who are interested may look into some positioning articles in this area (Bi, 2011; Bi et al., 2007, 2008); however, the specific work on the responsiveness to deal with job delays are limited. In this section, the most relevant literature is reviewed and classified into *system development*, *evaluation of responsiveness*, *information systems for rapid responses*, *leanness*, and *software tools for service managements*.

2.1. Development of rapid response systems

Researches on the development of rapid response systems have been conducted on system frameworks, analysis of system requirements, design methodologies, and industrial applications. Jan et al. (2010) presented an approach to manage the parts in the supply chain, their objective was to offer rapid manufacturing services, and the potential benefits to the aircraft industry were illustrated. Lluis (2002) developed a methodology to enhance the leanness of a production system; the methodology was proven successful to reduce wastes, increase productivity, and substantially reduce times on services. Jari and Harri (2004) introduced a fast production system in the electronic industry and suggested that fastness means to deliver the products to customers shorter than the expected lead-times; in addition, they argued that the standardized practices and modularized product designs can be helpful in implementing fast production. From the perspective of coordination, Samer and Yan (2006) emphasized the importance of experts' knowledge and interactions for the enhancement of the fast response capability of companies. As far as the medical applications are concerned, Bradford and Eliseo (2007) strongly suggested that rapid response systems have to be promoted as a potential model to identify and interact with potential patients who are experiencing the deterioration in their hospitalizations.

2.2. Evaluation of responsiveness

Researches at this aspect are performed on the evaluation models of responsiveness, analysis of responsive requirements and components. Pedro et al. (2009) investigated the impact of labor flexibility and machine flexibility on responsiveness of a production system in the clothing industry. Yanbing et al. (2012) stated that emergency response capacity is one of the most important design criterion for an emergency management system; they presented a hierarchy evaluation system to assess the emergency responsiveness. In their evaluation, the system-level responsiveness consisted of process capability, forecasting capability, support capability, and post-disaster process capability; furthermore, the process capability was assessed based on the rescue speed, command authority, collaboration, and the capacity of information transmission; the forecasting capability was evaluated based on monitoring and forecasting capability, warning and forecasting instrument, warning and forecasting accuracy, and information system facilities; the support capability was determined based on command communication capability, emergency resource reserve, emergency plan and simulation exercise, and security and education training; finally, the post-disaster process capability was evaluated based on the social support system, the evaluation and summary, and reconstruction capability. Vivian et al. (2010) developed a model for an emergency preparedness plan under the circumstance of a major economic capability disaster. That model was supposed to provide prompt warnings for substantive preparation activities. Jia et al. (2012) analyzed systematically on the demand-side interactive response capability for the power distribution in a smart electrical grid.

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