Integrating Lean and MRP: A Taxonomy of the Literature

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Abstract. The natural evolution of MRP and JIT has led to what we know today as ERP and lean production respectively. More than thirty years have passed since the introduction of JIT production into the Western world and since then, discussions regarding the dual existence of MRP and JIT persists in the operations management domain, though now more often in the form of ERP and lean. Needless to say, the dual existence of the two systems has led to an interest amongst both academics and practitioners about the comparability and compatibility of the two approaches. The aim of this paper is to review the literature that focusses on the compatibility of the two. As such, we present a taxonomy of the lean and MRP integration literature.

Keywords: Lean Production; Just-in-Time; Material Requirements Planning; Manufacturing Planning and Control

Introduction

Material requirements planning (MRP) and JIT production are two most prominent approaches for production management and inventory control in manufacturing firms. MRP has been widely applied since the 1970s, whilst JIT production, relatively younger in its use in the West, was initially seen as "the magic bullet" by both practitioners and academics. JIT implementation is a demanding process and lacks the support of a standardized software package due to its initial detachment from information technologies. (Dixon, 2004). MRP, on the other hand, has more recently become the core of enterprise resource planning (ERP) software. A natural consequence of the persistent co-existence of MRP and JIT in industry is the emergence of the desire to compare the two systems, whether in the original form of MRP and JIT or more recently, lean and ERP. As such, the fundamentally different natures of the two approaches are a further contributor for the interest in such a comparison.

Perhaps the most important contributor to the notion of mutual exclusivity of MRP and JIT systems is the prevalence of "push" and "pull" terminology used to denote the control strategy of material and information flow (Hopp and Spearman, 2004). For

many, MRP control, which centrally creates production orders, is viewed as synonymous for push; whereas JIT is viewed as synonymous for pull. In this paper, we use literature review to assess the history of MRP and JIT integration, and identify possible areas for further research.

Theoretical background: MRP, JIT, and Lean Manufacturing

On one hand, the term material requirements planning (MRP) refers to the MRP logic embedded in today's complex business software. In its most basic definition, MRP is a manufacturing planning and control (MPC) approach that relies on the principle of determining a schedule for the dependent demand items from the independent demand, through the processes of bill of material explosion, netting, and offsetting (Orlicky, 1975). Around 50 years after it first appeared, MRP planning is still accepted as the standard for determining the buying and making decisions of manufacturing companies, answering the "What?", "How much?" and "When?" questions (Ptak, 2004).

On the other hand, lean manufacturing has its roots in JIT production, which is the most important component of the Toyota Production System (TPS). The term "lean" was popularized the book "The machine that changed the world" (Womack *et al.*, 1990). According to Schonberger (2007), lean manufacturing was in the first years of its creation of a term more or less equal to JIT production, which had entered the Western world already a decade earlier. Schonberger further argues that lean manufacturing widened in scope in later years by further associations with other Japanese manufacturing approaches, which were mainly quality centered, and also with further western enhancements on its JIT production core. In any case, lean is today a comprehensive concept encompassing areas other than manufacturing. JIT production, however, remains at the heart of lean manufacturing, unchanged since its maturity in Japan in the 1970s (Schonberger, 2007).

Taxonomy of MRP and JIT integration studies

In our taxonomy for classifying existing literature on MRP and JIT integration studies, we use four main categories: conceptual, analytical, empirical, and information systems. As the names suggest, conceptual studies offer a conceptual model of an integrated control system, whereas analytical research makes use of mathematical models and simulation to test the effectiveness of such hybrid systems, usually limited to the shop floor test of combined push-pull principles. Empirical integration research denotes research carried out in a case company. In this category hybrid control models are developed by taking the particular manufacturing environment in the company into account and developing specialized solutions. The final category, which we call information systems research, deviates from the previous three in that the focus is not

on suggesting exhaustive solutions, but rather highlighting the software aspects of integration.

Conceptual Approach

Conceptual integration studies have usually had a more general approach to MRP and JIT integration as compared to empirical integration studies and analytical integration studies. As such, a number of conceptual integration studies do not present a detailed hybrid control system, but offer only a high level description of the features of possible hybrid solutions, if not merely presenting the motivation behind the search for a hybrid system (Belt, 1987; Lim, 1985; Vaughn, 1988).

Conceptual integration studies almost exclusively agree that JIT is a perfect shop floor control tool, whereas MRP has excellent planning capacity. This realization, which had already been revealed by MRP JIT comparative studies, prepared the stage for integration studies. However, among conceptual integration studies, those which propose a clear hybrid model definition follow two divergent paths. The first of these paths tries to combine MRP and JIT in a manner that they keep their original character and slight modifications are needed to enable their co-existence in a hybrid manufacturing system. Hence, the name "combination studies" would be more appropriate for these studies. The hybrid models in the other group of studies represent true integration in the sense that one or both of the MPC systems undergo a fundamental change to create the hybrid system. Therefore we will coin here this category of conceptual integration studies as "modified MRP" studies.

Among the "combination studies", Flapper *et al.* (1991) and Lee (1993) represent the main contributions. These models (and a subset of studies inspired from them) set MRP as the main framework, which carries out planning and control tasks as a regular MRP system would. The difference is that the MRP controlled area of production is restricted and a subset of production with repetitive characteristics, which is otherwise suitable for JIT production, is organized into production cells controlled by JIT principles. Thus, MRP computation and production complexity is greatly reduced, while shop floor control is facilitated and optimized by JIT production cells. Both Lee and Flapper et al. suggest that MRP can control the final output of production cells by providing only a final assembly schedule.

The most significant "modified MRP" study is that of Nagendra (1999), who proposes a hybrid model where the number of Kanban cards in the system is MRP controlled. However, the number of Kanban cards is not controlled for an entire production cell, but for each pair of workstations in the production system, which is closer to a job shop than repetitive mass production. Since workstations can produce a variety of component parts for multiple downstream workstations, creative solutions are needed to determine job priority and lead time, which is a necessary input for the calculation of the number of Kanban cards. In the proposed solution, job priority is determined through a one-time calculation of the optimal solution, stored in a database for each possible combination of work-in-process levels and work amounts at the downstream stations and their upstream pair. Nevertheless, the model proposed by Nagendra (1999) is not in total agreement with lean principles as it tries to achieve optimization through computation rather than empowerment of the shop floor workforce. The real-

ization of lead time and work priority determination also relies solely on a heavily computerized shop floor, which increases the volume for both data entry and handling.

Analytical Approach

For the majority of studies in this category, comparison is not just between pull and push control principles, but rather one or more hybrid control principles are compared to pure pull or pure push strategies in the search of the advantages of the optimized hybrid system. A smaller group of analytical integration studies begin with the premise that an integrated control is inherently better than simpler control techniques. This group exclusively tests changes in hybrid systems and in the manufacturing parameters focusing on the fit of the hybrid system to the manufacturing environment rather than the advantages it would provide.

Complex mathematical analysis and simulations provide the means for performance comparison of different control techniques in manufacturing environments ranging from simpler systems with few processes to more complex manufacturing environments such as multistage production environments with multiple lines, also with parallel configurations. In all of these manufacturing environments, optimized hybrid systems consistently out-perform simpler control principles in the different dimensions of inventory performance and service level (e.g. Deleersnyder *et al.*, 1992; Hirakawa *et al.*, 1992; Hodgson and Wang, 1991; Takahashi and Soshiroda, 1996). Deleersnyder *et al.* (1992) show that hybrid systems keep much of the control simplicity that Kanban systems offer, while dealing better with the uncertain demand through maintaining the push component. Takahashi and Soshiroda (1996) and Hirakawa *et al.* (1992) use the variability of production quantities and inventory level at each stage as the performance criteria in their mathematical model of a multi-stage production inventory system. Both report that hybrid systems are associated with smaller variability, and changes in demand variation don't change this fact, although it has an effect on the best configuration of the hybrid system, in other words on the place of push-pull boundary. Furthermore, pull in downstream combined with push at upstream produce superior results compared to the reverse case. Hodgson and Wang (1991) use simulation rather than a mathematical model to test their hybrid system in a much more complex manufacturing environment. However, the result remains the same and hybrid systems continue to be associated with better performance. Both Ding and Yuen (1991) and Geraghty and Heavey (2005) arrive at similar results from their respective simulation studies. Finally, Huq and Huq (1994) show that even in a job shop manufacturing environment that is traditionally associated with MRP control, JIT control principles (when embedded in the existing MRP system) have quite consistent and comparable performance levels, even if important manufacturing parameters like variations in setup times and process times undergo significant changes.

Despite their simplifying nature which cannot take all the components of JIT production into account, analytical integration studies consistently find in a variety of manufacturing environments that an optimized push-pull hybrid system performs better than a pure pull or pure push environment.

Empirical Approach

Research in this category is especially valuable in that it provides us with concrete examples of the viability of the previously described conceptual models and gives further insights about integration problems and opportunities. For example, Marques and Guerrini (2012) present a case study about a Brazilian metallurgical company that produces agricultural machines, which provides an especially interesting perspective on MRP JIT integration. The authors suggest that the case company does just the opposite of what the majority of American companies transitioning from a traditional MRP to a JIT MRP system do. The company began to implement an MRP system as part of the manufacturing planning and control in the company, which surprisingly until that time had completely relied upon lean production principles. Foo and Kinney (1990) also provide a case study where we meet the characteristics of the conceptual models that were presented in the combination studies (applied in a complex manufacturing environment). The case company is a telecom equipment manufacturer with a product variety which is almost limitless. In addition, demand variability is also quite high. The product and demand characteristics of the company seem to again have little room for the JIT practices imposed by a possible hybrid MPC tool. However, as in the previous case, the conviction is that JIT techniques in general and pull shop floor control in particular could improve shop floor performance significantly.

Finally, Lee and Shin (1996) present a case study of a Korean washing machine producer making the transition to an integrated MRP JIT system in response to the company's increasing product variety coupled with increasing demand volatility. Old product and planning structures, however, pose a challenge for such a change. Thus, BOMs will need to undergo radical change, in that modularity is increased and decreased levels will correspond to different planning horizons. This change facilitates a multi-level planning approach with rolling plans and time fences as in a typical JIT production environment, and shop floor control can be transferred to JIT production. Although not specifically stated, MRP seems to be in control of most of the purchasing and a mediator for planning in this case study, as in the hybrid models previously described in the combination studies.

Information Systems Approach

Initially, JIT proponents were against highly computerized production control, since this was thought to complicate and slow down the simple information flow achieved through the use of manual Kanban (Plenert and Best, 1986; Sugimori *et al.*, 1977). Thus JIT was considered incompatible with "high-tech production" and complex information systems in particular, as MRP-based software gradually became more and more complex and comprehensive. In their review of MRP JIT integration, Benton and Shin (1998) report that the issue of interfacing existing MRP systems with the newly implemented JIT systems is rarely referenced, although there is abundant research on JIT implementation and problems in its implementation stages. Considering the lengthy coexistence of JIT and MRP during the implementation of JIT, often resulting in a permanent coexistence, the somewhat disinterest in their integration is certainly related to the limited nature of JIT software packages. Earlier JIT software packages were typically supportive in few aspects of JIT production rather than

providing company-wide solutions as a result of the underestimation of information systems' role in the performance enhancement of JIT production. On the vendor side, the trend to integrate MRP and JIT software had actually already commenced in the late-1980s following the trend of MRP JIT integration (Discenza and MacFadden, 1988). Similar to Benton & Shin, Discenza and MacFadden also note the academic disinterest in software integration at that time, in light of the interest of providing conceptual and analytical models of integration.

In more recent years, however, a swift change has occurred in the conviction that ERP is far from providing the software support needed for lean production. The onset of the notion that ERP could in fact be supportive for lean production is partly related to the lean offerings of ERP vendors, but by no means excludes the possible contribution of the standard ERP functionality to lean production. According to Riezebos *et al.* (2009), ERP systems are in many aspects supportive for the principles of lean production. They claim that the standardization of jobs and facilitation of communication with the suppliers are among the most important lean supporting functionalities of ERP systems.

While there might be some possibilities for standard ERP systems to support lean production practices (although possibly with the need for some bolt-ons), a growing trend amongst ERP vendors is the marketing of "lean ERP" packages. For example, Bradford *et al.* (2001) provide an overview of the leading ERP vendors' lean ERP solutions in an exploratory study, whilst Powell *et al.* (2011) provide a more comprehensive list of the key areas of support, which incidentally could be provided both by traditional ERP systems and more contemporary ERP solutions with lean modules and functionality. What is more, the lean functionalities listed provide support for both lean practices for planning and production and also a limited number of more general lean tools. Powell *et al.* (2013) also present a pioneering study among lean and ERP integration case studies in that it sets out to develop a methodological framework for the dual implementation of lean and ERP.

Conclusion and further work

Our literature review on MRP JIT integration reveals that it became a much more widely accepted and researched area especially after ERP systems became commonplace software and a lean ERP trend started to emerge. Although it is by no means an easy task to reconcile JIT production with ERP systems and a variety of ways exist for this purpose, today the necessity of IT support for JIT production is undisputed (Dixon, 2004). However, the remaining questions are "how" and "where" the integration should take place. The question "how" is an extensive question with both theoretical and practical implications. With regard to theory, it relates to questions such as should the integration take place through combination or modification? Which of the control principles should be used as the main framework? And how should the control responsibility be shared among the two control principles? In terms of practicality, on the other hand, it concerns the practical means to interface the two systems in general and the use of information systems for this purpose in particular. The second question

of "where" can also be broken down into two questions: which manufacturing environments are feasible for hybrid system use? And what should be the criteria for matching the right hybrid system with the right manufacturing environment among the various combinations?

Our literature review revealed that some of the above questions have only partial answers in the existing literature. The questions regarding "where" are especially neglected, as the majority of integration studies are not very clear about the application area of the proposed hybrid models. Practicality comes next, as the information systems approaches towards integration have only currently started to attract academic attention with the rise of "lean ERP". Thus, further work should present answers that address these questions, perhaps through the development of further conceptual models of integrated systems. We also suggest that there is a distinct need for more empirical studies in the field of MRP JIT integration.

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