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Lean Production and information technology: Connection or contradiction?

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ABSTRACT

The principles of Lean Production have enabled organisations in the manufacturing and service sectors to significantly improve their competitiveness. The application of Lean principles, derived from the Toyota Production System has enabled many organisations to simultaneously improve productivity, quality and customer service. Similar benefits have been achieved through the application of information technology (IT). The application of IT and Lean principles are claimed to be interdependent and complimentary by some; whilst others have seen as the approaches as being mutually exclusive.

This article presents reviews the role of IT in achieving the principles of Lean Production. Three important topics are reviewed: the use of IT in production logistics; computer-aided production management systems; and advanced plant maintenance. It is shown that the roots of different ways of working were similar, but that subsequent developments followed in opposite directions. Later, when the acceptance of Lean Production became more pervasive, the practices typically converged into hybrid production systems, applying elements of several systems in a way that is consistent with the principles with Lean Production.

1. Introduction

In 1977, Sugimori et al. published the first paper on the principles of the Toyota Production System that was written in English [1]. They stated that the use of computer systems for organising production logistics would introduce unnecessary cost, over-production and uncertainty. Instead, they focused upon Kanban (card) systems because of their simplicity and robustness. The Kanban was described as an information system in its own right: "It is only the final assembly line . . . that can accurately know the necessary timing and quantity of parts" (p. 555). As also noted by New [2], this approach made a striking contrast with that of contemporary Western companies, in which information technology and advanced automation was often seen as the way to gain competitive advantage (for example, General Motors invested $70 billion on information technology and automation [2,3]). Interestingly, a common misperception at that time was that information technology and advanced automation were the main success factors of Japanese production practices [4]. It is now realised that the Japanese approach was not rooted in the use of information technology [5–8]. Nevertheless information technology does have a role to play in achieving excellence in production. The aim of this article is to review that role through a thorough literature review.

Herron and Braiden [9] presented a three stage maturity model that described the application of Lean Production techniques.

The first stage, Gemba Kanri (Workshop Management), stabilises the manufacturing system to ensure that processes are controlled and reliable [9]. The aim of the second stage is to achieve maximum productivity through the application of just-in-time principles. During the third stage, the organisation focuses on further incremental improvement steps [9].

This paper reviews the literature relating to the use of IT in Lean Production. It takes a historical perspective and outlines the development of production control and Lean; computer-aided production management (CAPM) systems and ERPs and advanced maintenance. The review outlines Western and Japanese perspectives and shows convergence in the approaches adopted.

Organisation of the paper: In Section 2, the role of IT in the design and implementation of production control systems is described. Section 3 considers the application of computer-aided production management systems and enterprise resources planning. Section 4 discusses the use of IT in organising plant maintenance. Section 5 provides a discussion and conclusions.

2. Production control systems and Lean principles

In 1977 Sugimori et al. [1] wrote the first major paper on the Toyota Production System that was written in English. In the west,

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the late 1970s had seen an explosion of interest in material requirements planning (MRP), which became known as 'the MRP crusade' [10]. There was also a strong interest in numerically controlled machine tools and advanced automation. In the west, there was a view that an automated factory was less vulnerable to worker militancy [2]. In contrast the Japanese were focusing upon just-in-time/Lean methods rather than using computerised tools. They also had a preference for low cost automation and relatively simple manufacturing technologies. Sugimori et al. [1] commented that the Kanban (card) system had various advantages over computerised approaches: (i) the cost of processing information was reduced; (ii) it was better at recording and communicating information in a dynamic environment; and (iii) the demand for all items was synchronised. The Japanese considered Kanban systems to be more transparent; workers could understand the status and requirements of production without having to access and navigate complex software. In fact, Sugimori et al. [1] criticised the lack of respect for humans in production organisations controlled by computerised planning systems. Sugimori et al. described how Kanban delegated control decisions to foremen and workers, rather than adopting centralised decision making, which was the approach adopted by MRP.

2.1. Historical background of production planning and control systems

The Kanban system was developed at a time when economic order quantity (EOQ) systems were widely used. The assumption behind the use of EOQ was that cost advantages could be gained through making an optimum trade off between inventory holding costs and re-ordering costs. Both the EOQ model and inventory reordering systems originated from the work of Harris [11,12]. Whereas the Kanban system uses small transfer batches, EOQ systems independently determine 'optimal' process batch sizes for parts and products, resulting in a large variety of order quantities. Burbidge had strong objections against the use of EOQ, which he described as "pseudoscientific nonsense" [13, p. 18]. Burbidge argued that real cost advantages would arise from improving the material flow system with a balanced ordering of parts, based upon explosion of end product demand [14]. EOQ is a simplistic model; it does not take into account the variability of cost factors, stock outs or the costs arising from a lack of co-ordination in the system. These extra costs become particularly visible if demand or product designs change, which can result in stock that cannot be sold. The irregular loading of the production system will entail extra co-ordination or capacity costs. The Kanban system was designed to use small lot sizes and hence to prevent these problems from occurring [13,15].

EOQ systems have been widely used by practitioners and researchers since the beginning of the 20th century. Mabert [10] described various attempts to calculate synchronised inventory requirements before and during World War II. Benders and Riezebos [16] showed that the periodic batch control (PBC) systems are effective at synchronising demand. Burbidge [17] was one of the first researchers to propose a modification of the EOQ system that took into account the relationships between products and parts. This Standard Batch Control (SBC) system synchronised the ordering of a small batch of products with the (re)ordering of exactly the correct amount of components.

The Kanban system can be considered to be a special type of SBC system. It assumes that orders for parts for a parent item are divided into several transfer batches of standard size. The time between issuing these transfer batches is slightly longer than the time needed to refill inventory. The small and standard transfer batch size creates an efficient and regular flow of material. The Kanban system therefore balances material flow throughout the manufacturing system [15].

However, there are some differences between Kanban and SBC systems. Kanban is a visual mechanism that gives shop floor workers control of the production process, whereas SBC was developed for use by centralised planning departments. In Lean Production the planner is responsible for setting the transfer batch size for Kanbans and for additional procedures, such as level planning that aims to avoid unbalanced loading of different stages of production stages. However, the decision to start the production of a batch, is under the direct control of the shop floor employees [15].

2.1.1. A dynamic world

After World War II the industrialised countries faced a steady increase in demand. Many production facilities had to be rebuilt, as many had been destroyed or reconfigured in order to supply military products. In the post war years the modernisation and rebuilding of industry created a strong increase in the demand. However, resources were scarce, so improving efficiency became a critical issue. In the west, improvements were generally achieved through increasing set up batch sizes, but this made throughput times longer [16]. There was a lot of local optimisation and the effects on inventory and flexibility were often overlooked.

Systems theory and, more specifically, industrial dynamics, did take into account the relationship between the parts of a system and the time varying behaviour. Forrester [18] studied dynamic systems that consisted of time-sequence relationships and amplification behaviour. He observed that the response to a change is generally exaggerated compared to the response that could be reasonably justified by the magnitude of the change. This behaviour has been observed in the ordering behaviour in succeeding stages of the supply chain. The variability in demand increases through the supply chain [19]. This phenomenon is commonly known as the Bullwhip, Whiplash or Forrester effect. The main causes for this erratic or nervous behaviour were found to be due to: (i) a time delay in the information feedback system; (ii) the use of incorrect inventory policies such as increasing safety stock as demand increased; and (iii) the use of statistical forecasting techniques which assumed that the historical demand patterns would prevail in the near future [15]. The effective management of inventory and lead-times therefore requires coordination throughout the supply chain.

The literature on industrial dynamics had an important impact on the design of planning systems. There was more focus on the integrated control of the supply chain, by using the information of end product demand in the control of each manufacturing stage. The important principle of linking product and component demand through a bill of materials explosion, which was known before WWII, was rediscovered. The development of computerised information systems reduced both the required time and the costs of integrated control. Many of the early books on MRP (e.g. [20–22]) paid attention to the detailed options within the systems, such as advanced lot sizing rules. However, the important design parameters, such as lead time offsets, bill of material structure, safety stocks and lot sizes, did not receive particular attention in this early work [10]. This often compromised the quality of the underlying data model within MRP systems, which limited their effectiveness. In consequence, industry became sceptical about the potential of these production planning systems [10]. The result was a tendency to use the systems mainly for administrative purposes such as ordering, maintaining the bills of materials, as well as recording price and lead time information. They were also used for tracking and tracing inventory.

2.2. Production planning systems

The popularity of cyclical planning systems [23–25] and visual control systems including Kanban [1], ConWIP [26,27] and Polca [28,29] has grown rapidly over the last few decades. A major