Available online at www.sciencedirect.com

ScienceDirect

IFAC PapersOnLine 51-11 (2018) 140–143

Kanban for Lean Production in High Mix, Low Volume Environments

Daryl J. Powell

Norwegian University of Science and Technology, Trondheim, Norway (e-mail: daryl.j.powell@ntnu.no).

Abstract: Due to its assumed inherent inability to manage custom-engineered parts and components, the Kanban system has traditionally been disregarded in high mix, low volume "engineer-to-order" environments. However, elements of the Kanban system have proven their worth in other turbulent, non-manufacturing environments, such as software development. In this paper, we draw on two case studies from the Maritime sector where Kanban boards and cards have been introduced for the execution phase of shop orders in manufacturing. Initial results have been exceptional, with 50% reduction of lead-time realized in both cases.

Keywords: Lean, Agile, Kanban, Pull system, High mix, Low volume.

1. INTRODUCTION

Jones and Womack (2017) describe lean thinking and practice as the most successful approach to business improvement of our generation, suggesting that it has outlasted many other improvement approaches and has been taken up by organizations in all kinds of industries across the world. However, when maintaining a focus on manufacturing industry, the seminal work of Ohno (1988) describes lean production as an alternative way of organizing mass production, suggesting that large volumes are intrinsically associated with the lean production paradigm, at least in the traditional sense. This has led to significant challenges when attempting to apply lean production in high-mix, low-volume environments, such as those in engineer-to-order (ETO) manufacturing (Powell & van der Stoel, 2017). For example, the basic principles of mass and flow production (Woollard, 1954) state that:

a) Mass production demands mass consumption; and

b) Flow production requires continuity of demand.

ETO manufacturers exhibit neither of these traits, thus an alternative approach to "traditional" lean production is required in order to materialize the fundamental lean principles for such ETO environments.

2. THE KANBAN SYSTEM: MATERIALIZATION OF JUST-IN-TIME PRODUCTION

Sugimori *et al.* (1977) describe the Kanban system as the production control system that was developed to materialize just-in-time production - "*an important factor in an assembly industry such as automotive manufacturing*" - and a fundamental part of the Toyota Production System. In the Kanban system, a form of order card called "Kanban" is used together with supermarkets of standardized parts and / or components. These supermarkets contain a pre-determined and strictly limited amount of inventory, calculated to ensure that on-hand inventory is just enough to cover the replenishment period for replacement stock.

In this instance, a Kanban card is a signal that provides the authorization to order or produce parts such as to replenish those which have been consumed from the supermarket – in a "take one, make one" fashion. However, on examining the Japanese Kanji characters that make up the word Kanban, we discover that Kanban actually refers to the signboard on which the so-called Kanban cards were typically displayed:

看

板

Fig. 1. Kanji characters Kan Ban

Fig. 1 shows the Kanji characters for Kanban. The first character – Kan – is made up of the symbols for *hand* and *eye*. It represents a man shielding his brow in order to see clearly, and means "*to look at closely*". The second character – Ban – is made of the symbols for *tree*, *wood*, and *wall*. It represents a wooden board leaning against a wall, and literally means "*wooden board*". In essence, then, Kanban means "*to look closely at the wooden board*".

As such, Kanban can simply be translated as board, and provides an effective form of visual management for production control in any environment. This is in fact reflected rather well when one considers the application of

2405-8963 © 2018, IFAC (International Federation of Automatic Control) Hosting by Elsevier Ltd. All rights reserved.
Peer review under responsibility of International Federation of Automatic Control.
10.1016/j.ifacol.2018.08.248

lean thinking and practice in software development and project management, for example, where the agile approach promotes the use of Kanban in its more primitive sense – the signboard. (Interestingly, Project Management Insititute (2017) describe Agile and Kanban as subsets of lean, as they are "*named instances of lean thinking that share lean concepts such as focus on value, small batch sizes and elimination of waste*" (p. 11), see Fig. 2).

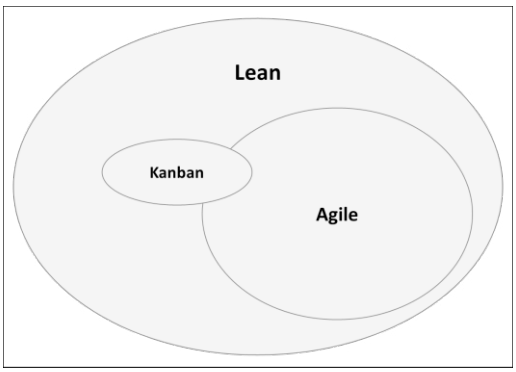

Fig. 2. Agile and Kanban as subsets of Lean (adapted from Project Management Institute, 2017)

3. KANBAN BOARDS: AN EFFECTIVE PRODUCTION CONTROL MECHANISM IN HIGH-MIX, LOW-VOLUME ENVIRONMENTS?

The remainder of this paper seeks to investigate if Kanban in its most primitive form – a signboard – can serve as an effective means to manage the production control task in high-mix, low-volume environments.

Kanban has for some time been used as a work-visualization mechanism in agile software development, where Kanban boards and daily stand-up meetings have been the primary mechanisms for success (see for example Kniberg & Skarin, 2010). The three key foci of Kanban can be described as:

1) The materialization of information flow

2) The visualization of work flow

3) The restriction of work-in-process (WIP)

Achieving these features enables successful and accelerated coordination and control of the flow of work. An illustration of a basic Kanban board can be seen in Fig. 3, below.

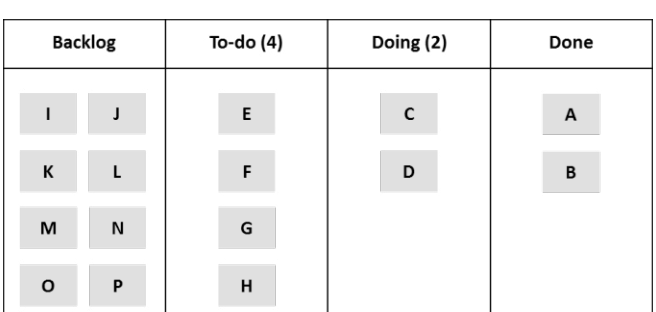

Fig. 3. Kanban board (Powell and van der Stoel, 2017)

Notice how the Kanban board is used to visualize and materialize available work, work-in-process, and completed work (in this case jobs A-P posted under the headings "Backlog" and "To-do", "Doing", and "Done", respectively).

Each day, all team members gather around the Kanban board in what's known as a daily huddle, scrum, or stand-up meeting (typically maximum 15 minutes long). During this meeting, the participants discuss what was achieved on the previous day, the plan for today, and any problems that may need to be addressed in order to achieve the plan. In this manner, Kanban also encourages, promotes and fosters collaboration and team-based problem solving to increase throughput in the production system.

Based on the constant work-in-process (ConWIP) principle, the Kanban board explicitly limits the amount of tasks that can be assigned. In Fig. 3, this is indicated by the (4) and (2) in "To-do" and "Doing" respectively. Having set a limit for WIP, or what Hopp & Spearman (2004) refer to as a WIP-cap, a pull mechanism is created in the Kanban board. For example, by following the general pull-principle of "one-out-one-in", as soon as one of the jobs C or D are completed, capacity becomes available to process one of the "To-do" jobs, E-H. This subsequently releases capacity for the next task from the "Backlog" to be pulled into "To-do". Team members are empowered to manage the workflow by moving the cards across the board themselves, in real-time.

4. APPLYING KANBAN IN PRACTICE: TWO CASE STUDIES FROM THE MARITIME SECTOR

We now consider the application of Kanban in two case studies from the Maritime sector. Both cases experience high levels of turbulence in high-mix, low volume environments. With 22 employees and revenues in 2017 of approx. €1.8M, case one assembles, tests and calibrates underwater sensors for environmental monitoring. Case two has 120 employees, and with revenues of approx. €6M (2017) develops and provides camera products and systems to the maritime industry. In case two, this investigation focuses primarily on the customer support department, which provides services for inspection, diagnosis and repair of bespoke underwater camera equipment. Both cases represent team sizes of 5-9 employees. We use data collected from 2016 (pre-Kanban) and 2017 (post-Kanban).

4.1 Case one: Sensor

Prior to Kanban implementation at case one, production work orders were simply posted on a central white board, or production board, as shown in Fig. 4.

Though important information such as customer ID, due date and product specification was readily available to the team, the documents on the board were primarily used by the production manager to assign work tasks to associates.

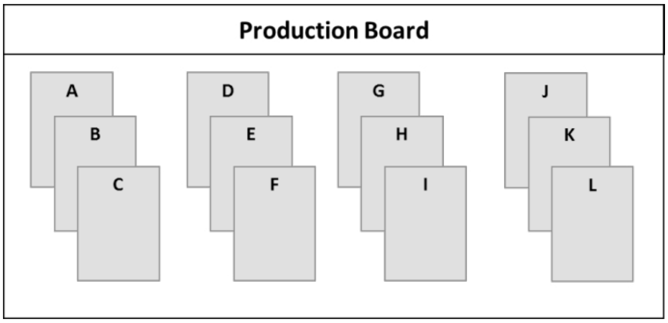

Fig. 4. Production board, case one (pre-Kanban)

Following an analysis of current delivery performance, it was decided that a more effective method for production control was required, and a Kanban solution was designed, as shown in Fig. 5.

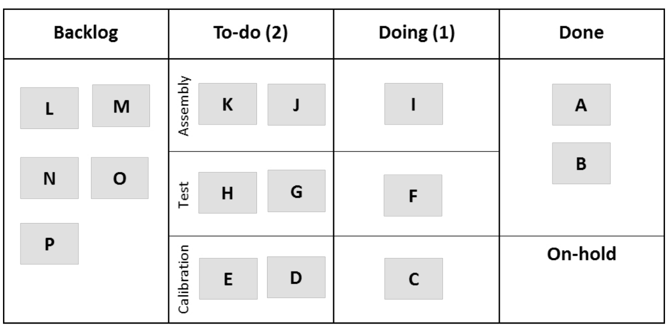

Fig. 5. Kanban board, case one

In the Kanban solution at case one, jobs flow from Backlog through "To-do" and "Doing" in each of the segregated operations, "Assembly", "Test", and "Calibration". The pull system is materialized in that when job C is completed (see "Calibration", "Doing"), either of jobs D or E (which are currently waiting for calibration) can be subsequently pulled into "Doing" status in the "Calibration" operation. When job F is complete in "Test", it will move to "To-do" in "Calibration", freeing capacity in "Test" for either job G or H. This pull mechanism continues backwards through "Doing" and "To-do" in "Assembly", eventually creating capacity in "Assembly" for the next job to be released from "Backlog". "On-hold" was added for jobs which must be removed from the primary flow for a specific reason, for example awaiting input from customer. It is important not to abuse the "On-hold" function, for example in light of "hot jobs". The team must always respect the flow imposed by the Kanban board.

4.2 Case two: Camera

Prior to Kanban implementation at case two, work packages were distributed to individual team members by physically posting work orders in document containers at each workbench. It was recognized that this did not give a satisfactory overview of jobs currently in the system, and was particular sensitive to disruptions should a team member be absent due to sickness, for example. The team was also unsatisfied with current delivery performance, and it was recommended that the team implement a Kanban solution, with the design shown in Fig. 6.

The work waiting in the backlog represents jobs that have been quoted to customers, but which still require acceptance and a purchase order (PO) from the customer. Once a PO has been received from the customer, the job is moved into "To-do" and prioritised at the next stand-up meeting. As such, new jobs ready to be processed are posted in "To-do".

During the daily stand-up meetings, the progress of jobs in "Doing" is discussed and any problematic issues shared and discussed with the team. This part of the board is divided up across seven resources, representing each of the seven customer support operators in the team. The highest priority jobs from "To-do" are then added to "Today" and prioritised against any jobs still remaining since the previous stand-up meeting (e.g. jobs L & N). These jobs are not allocated to any particular team member, but should be pulled into "Doing" by the customer support operators on the completion of any of the jobs C-J. Once "Today" jobs are allocated, operators continue to pull the remaining "To-do" jobs into "Doing". Completed jobs are moved to "Done" and subsequently closed out in the electronic planning system.

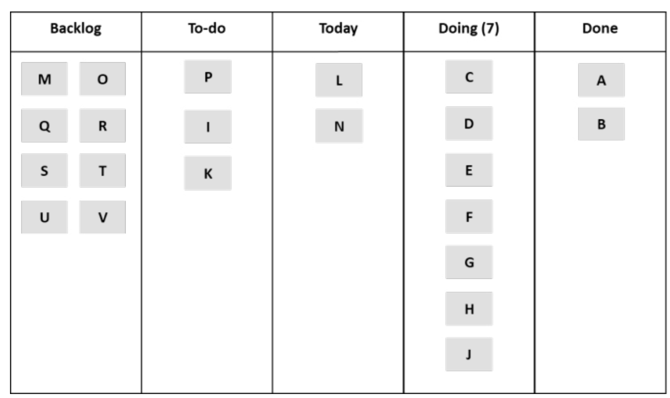

Fig. 6. Kanban board, case two

5. RESULTS

The results shown in Table 1 suggest that Kanban boards are an effective means for production control in high-mix, low-volume environments (2016 data is pre-Kanban and 2017 post-Kanban).

Table 1. Results: Lead-times at Sensor and Camera

	Sensor: LT	Camera: LT
2016	12 weeks	42 days
2017	6 weeks	20 days

Case one experienced an average lead-time (LT) reduction of 50% following the implementation of a Kanban solution for assembly, test and calibration of sensors. Case two also realized a lead-time (LT) reduction of over 50% following the implementation of its Kanban solution for inspection, diagnosis and repair of camera systems.

6. CONCLUSIONS

By drawing on two case studies, this paper provides an interesting account of applying a simple visual technique – Kanban – for administrating the production execution task in high-mix, low-volume environments, such as those encountered in ETO manufacturing. As such, this piece of research is relevant for both research and practice.

Research on the application of Kanban systems in production environments must expand to consider Kanban in its most primitive sense – the signboard. This work suggests that one particular reason for the challenge of realising pull and flow production in ETO environments has been the over-emphasis on Kanban as the “card” and “supermarket” parts of Toyota’s Kanban system, offering little emphasis on the board itself. For this, production researchers must look towards other fields, such as agile software development and agile project management, for appropriate materializations of the just-in-time phenomenon.

Practical implications are twofold. Firstly, this research has shown how the Kanban signboard can be used to visualize and materialize workflow in high-mix, low-volume environments. By applying the ConWIP principle and setting strict limits for work-in-process (WIP), the Kanban board can be used to accelerate throughput in high-mix, low-volume manufacturing environments by introducing an effective pull mechanism based on available resource capacity rather than stock replenishment. Secondly, this work highlights the importance of the daily stand-up, which has emerged as a critical part of the Kanban process. A cross-functional workforce, self-directed work teams and multi-skilled operators have for many years been recognized as a success factor for lean manufacturing (e.g. Shah and Ward, 2003), and this is certainly no exception for the success of Kanban applications in ETO manufacturing, where the daily stand-up serves as the platform for collaboration and problem-solving, which should subsequently drive continuous improvement activities across the enterprise.

ACKNOWLEDGEMENTS

The author acknowledges financial support received from the Research Council of Norway (for the SoundChain and Lean Management projects) and EU Erasmus+ (the EuroLEAN+ project).

REFERENCES

Hopp, W.J. and Spearman, M.L, (2004). To Pull or Not to Pull: What Is the Question? *Manufacturing and Service Operations Management,* 6(2), p. 133-148.

Jones, D.T. and Womack, J.P. (2017) *The evolution of Lean Thinking and Practice.* In: Netland, T.H. and Powell, D.J. [EDS] The Routledge Companion to Lean Management. Routledge, New York.

Kniberg, H. and Skarin, M. (2010). *Kanban and Scrum: Making the most out of both.* C4Media.

Powell, D.J. and van der Stoel, A. (2017) *Lean Engineer-to-Order Manufacturing*. In: Netland, T.H. and Powell, D.J. [EDS] The Routledge Companion to Lean Management. Routledge, New York.

Project Management Institute (2017) *Agile Practice Guide.* Project Management Institute, Inc., Pennsylvania.

Shah, R. and Ward, P.T. (2003) Lean manufacturing: context, practice bundles, and performance, *Journal of Operations Management,* 21(2), p. 129-149.

Sugimori, Y.; Kusunoki, K.; Cho, F. and Uchikawa, S. (1977) Toyota production system and Kanban system: Materialization of just-in-time and respect-for-human system, *International Journal of Production Research*, 15(6), p. 553-564.

Woollard F.G. (1954). *Principles of Mass and Flow Production*. Iliffe and Sons, London.