Just-in-time Production

A comparison of Kanban and CONWIP

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Abstract: The principal objective of this paper is to achieve a greater understanding of just-in-time production tools as kanban and CONWIP. Both tools are used in pull production systems to control the level of WIP (Work In process). An explanation of pull production system stresses the importance of controlling WIP levels in a strongly competitive environment. The aspect of how to achieve controlled WIP levels in a pull production system is explained further by studying tools as kanban and CONWIP. For the research, articles in the chosen area have been studied. Also other literature covering the subject has been examined. Different sources as Emerald, Discovery and Google Scholar has been used to find suitable articles for the literature study. Both similarities and differences have been found between kanban and CONWIP systems. Both systems objective is to control the average WIP at lowest level without starving or blocking the flow. Kanban uses signals to control each workstation and CONWIP uses a single set of global cards for controlling the amount of WIP for the whole system. Both systems are responding to customer demand and a pull reaction of a material need up-stream is created. It can be clearly said that literature answers contradictory to the question which system is superior. Several simulations have been carried out and most of them are in favour of the CONWIP system due to its ability to be flexible and use less WIP. Hence, there are different parameters and dependable factors that will affect the final performance that explains the different results. Several authors stresses the need of further research to be able to come to a consistent conclusion.

Keywords: Supply chain management, Push and pull production system, Just-in-time, Kanban, CONWIP

1 Introduction

A global competitive environment drive manufacturing companies all over the world to continuously make improvements of their manufacturing operations. By

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continuously improving, each company strive towards receiving a better competitive advantage. The world has become a constant changing environment with fast changing customer demands. The time to market is becoming shorter which puts further pressure on each company to be competitive. As Marek, et al. (2001) points out, traditional production systems have difficulty with coping with the fast changing environments and another system is needed to fulfil the demands of the customers. The traditional system as mass production is built up as a push system which "pushes" work through the production system to fulfil the forecast demand. Inventory is common to be high in these systems and the systems are struggling with long lead-times. A system more suitable for conditions of today is the just-in time system (JIT) which uses a "pull" instead of "push" thinking. JIT philosophy is based on achieving excellence by handling continuously improvements and reduce waste. By doing this Fullerton and McWatters (2001) consider that the production system can reach excellence by producing products with higher quality, lower inventory as well as being able to shorten lead-times. The pull system "pulls" the work through the production to fulfil actual customer demand. The WIP becomes restricted which means less inventory is needed. By reducing WIP, less tangible assets and inventory space are needed in the system. As Krajewski (2013) points out, lowering the inventory automatically stresses the system and make problems become visible. By this process appropriate actions can be taken. The pull system actually respond to the demand directly compared to the push system that produce products in advance.

This paper is focusing on two tools, kanban and CONWIP, which are tools used for controlling the flow and WIP in a "pull" production system. Both tools are developed from the JIT philosophy. The principal objective in this paper is to present a deeper understanding of these two tools and examine their similarities as well as differences and if one of the systems is superior. The study briefly begins with expanding the knowledge of the "pull" productions system and JIT, that both are part of lean production.

2 Research Method

To reach the principal objective, a literature study has been done to achieve a greater understanding of kanban and CONWIP tools that are used in JIT production systems. Several scientific articles has been examined as well as other literature that covers the studied area. To find suitable scientific articles sources as Emerald, Discovery and Google Scholar have been used for the literature study. The following search words were used: Supply chain management, Push and pull production system, Just-in-time, kanban and CONWIP. By using a broad search and thereafter narrowing it down made the search more effective and resulted in a broad range of articles covering the studied area. The most difficult part has been to find articles that present research from a relevant time period. Most of the articles and other literature used are published within a ten years period. It´s important to base research on original sources, therefore a few articles are exceeding this time limit.

The kanban system is more commonly presented in articles and books compared to CONWIP. It´s clear that more research has been done on the kanban system and how it is to be implemented. To justify both tools the author has taken this to account during the search phase. Several articles have tried to compare kanban and CONWIP system by simulation. Each simulation use different parameters and dependable factors which has made a comparison difficult. The author´s knowledge of simulation methods and articles sometimes contradictory answers have restricted the work. Hence, it´s clear that more research is needed in the studied area and that there still remain questions about which system is the superior.

3 The Pull Production System

To be competitive and keep up with a fast growing global market with demanding customer needs, it becomes important for each company to make continuously improvements in their production process to be able keep up their position or to gain new market shares.

Building a supply chain that is robust and agile enough to handle disruptions becomes of importance. By controlling flow of WIP by adjusting the level of inventory controlled by customer demand, a pull production system is created that support the production process resilience (Huang et al., 2014). In this system an inventory item is replaced when one has been consumed. It also means that replacement actions are taken more frequently compared to a push system. Further, Huange et al. (2014) explain that the replacement should be made in small batch sizes that are optimal from an economical perspective. Replenishment and production should be driven by actual customer demand instead of forecast demand. By ordering small batches frequently, waiting time for inventory can be reduced and it, in return, means reduced lead-time (Huang et al. 2014). The time from a customer making an order to the delivery will be shorten. Huange et al. (2014) also stress the importance of visualization of actual demand and the capacity in each link in the supply chain. By doing so the system fills up each inventory buffer that has been reduced in the supply chain by consumption. Forecast error can be reduced by pushing inventory upstream where forecast error affects the least. This action, Huange et al. (2014) point out, will also minimize inventory. The pull system has the ability to handle disruptions because it takes the system back to stable operations, while the push system is struggling (Huange et al., 2014).

Hopp and Spearman (2004) emphasize several benefits by implementing a pull system. WIP can be reduced as well as cycle times. By using a controlled mechanism, WIP can be regulated to act on a low level. The controlling mechanism lower variations which also implies that the production process flow will act smoother. Using a low WIP level makes the system vulnerable to loss and rework because it will shut down the flow. Defects automatically are taken care of directly because of the minimal average of WIP that are used. It means that problems are taken up to surface and act on, which automatically lead to better quality (Hopp and Sperman, 2014). They explain that by stressing the system by controlling WIP levels, costs can be reduced which also benefits the system compared to a push system. As Marek et al. (2001) point out, the ability to respond to changing customer demands makes the just-in-time production the best choice. However, situations makes companies decide between push and pull or a combination of both (Krajewski et al., 2013). Next, JIT philosophy will be explained further.

4 JIT – Flow and WIP control

The JIT philosophy is closely tied to the Toyota production system (TPS).Together with Jidoka (zero defects) they are the two main pillar in the TPS. JIT implies making certain that the right components, in the right time, in the right amount are available to the production (Segerstedt, 2008). Fullerton and Watters (2001) indicates that quality improvements, flexibility of the employees as well as lowering inventory and increase profits are benefits that can be required by implementing JIT. Segerstedt (2008) points out that time is central in lean production (TPS) and by dividing time into value-added and non-value-added time, non-value-added time can be eliminated. The total throughput time is of importance and eliminating non-value-added time will release time that can be used differently.

Hopp and Spearman (2004) emphasize that the pull production system is a part of lean production as kanban and other “pull” tools are part of JIT. Hopp and Spearman (2004) talk about lean as not only a philosophy about eliminating waste, it´s about goods or service production that produce with minimal buffer and costs. As Huang (2002) mentions, JIT philosophy is to make material and components needed to be available exactly when they are wanted. By having suppliers closely tied to the system, it will prevent the system from failing. It means, making certain transportation between suppliers is close and efficient and that the communication is optimized (Huang 2002). Further, it also means that the production system is efficient scheduled with short set-up times and of high quality. As White et al. (2010) point out, JIT uses a holistic view where its practise can contribute to quality being built into its foundation that becomes a solid ground for continuous improvements. Further, by organising technology in groups a flow of information and material can be created. By working close to the actual production, White et al. (2010) consider that relationship between employees and the company can be strengthen. The employee participation create an upward communication. They also stress that by practising JIT, workload can be smoothed by minimizing lot sizes and reduce the variation by using a production mix. It means that the workload is evenly scheduled and duplicable on a daily basis. JIT strength is the ability to respond to changes in the environment. A production must be able to react on uncertainties and volume changes rapidly (White et al., 2010). Further with an efficient organisation the organisation receive the ability to compete in costs and in this way strengthen its competitiveness.

5 JIT - Kanban and CONWIP system

Several benefits with a pull production system and the use of JIT philosophy has been studied. The question next to be answered is how these benefits can be achieved. Kanban and CONWIP are to be presented and are tools that are used to fulfil the requirements of a JIT production system. The major concept with these tools is to act as visible signals of requirements down-stream which “pulls” work through the production system (Li, 2011). Li (2011) explains that by levelling WIP a WIP cap is created by the amount of visible signals that detect inventory variation problems that have to be resolved. By using a WIP cap, Hopp and Spearman (2004) believe that WIP is prevented of expanding out of control.

5.1 Kanban

Kanban is a system controlling WIP and production flow in a JIT production system. Kumar and Panneerselvam (2007) proclaim that kanban works as a multistage scheduling system using less lead-time and WIP. It has the ability to handle high production volumes and use maximum capacity utilization. Further, the kanban controls the flow of parts along the down-stream process which create a “pull” action of material required (Kumar and Panneerselvam 2007). The kanban system uses cards to control WIP between each workstations (Marek et al., 2001). Hopp and Spearman (2004) explain that the process begins by the movement of an outgoing standard container at an outgoing stock point authorised by a move card. A production card is removed from the container. When a production card, a standard container with incoming parts and an idle work station is available production can start. Further, when a move card is removed from the container with incoming parts at the inbound stock point, production at the idle work station can start. The first thing the worker does is to place the move card in the hopper and then begin the process. When an authorization kanban card is received, material is pulled down-stream through the process chain (Marek et al., 2001).

There are two systems of kanban cards; “single card system” and “two card system” (Kumar and Panneerselvam, 2007). The “two card system” consist of processing and material movement, “single card system” of only material movement (Hopp and Spearman, 2004). A single buffer between close workstations act as a mode. It becomes an in- and outbound buffer for the workstations on both sides of the buffer mode (Kumar and Panneerselvam, 2007).

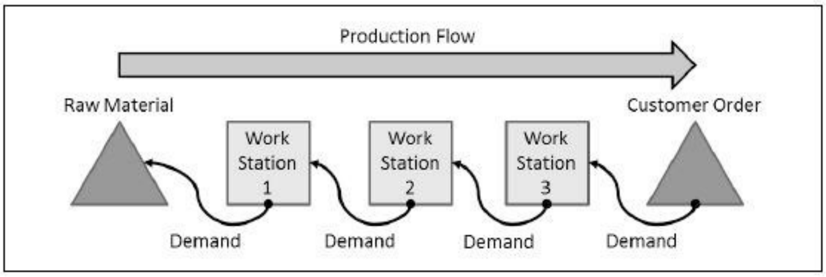

Fig. 1 A kanban pull-system (Gastermann et al., 2012 p. 558)

The consumption of WIP act as a trigger for order release up-stream (Takahashi et al, 2005). The kanban system uses controlled WIP at each station and actually constrains the flow, but in this way WIP is lowered to a lower average WIP (Hopp and Spearman, 2004). Hopp and Spearman (2004) explain further that constrains will cause problems and by solving these, a more efficient system can be created to a lower cost. Kumar and Panneerselvam (2005) agree and points out that when a buffer is at maximum level, further storage is prevented. The kanban system is signalling the maximum level due to its restrictions of the amount of parts or containers. Takahashi et al (2005) stress that holding WIP at each workstation can become a weakness due to the amount of processes in a production system.

The kanban system depend on the establishment of a number of cards, one for each workstation, to meet the performances of the production system (Framinan et al., 2006). Framinan et al. (2006) point out that rules have to be carefully decided on, due to future events of increasing demand or WIP excess.

5.2 CONWIP

CONWIP (Constant-Work-In-Process) is, as kanban, a system that controls WIP and production flow in a production system. Al-Tahat et al. (2008) consider that the CONWIP system has the ability to effectively utilize the resources within the production system.

CONWIP system uses one set of global cards for a complete production system (Gastermann et al., 2012). A CONWIP card is released when a finished product leaves the system. A new demand has been created and when the CONWIP card is released it authorizes new inventory to enter the production system (Marek et al., 2001). Marek et al. (2001) explain further that a CONWIP card stands for a constant level of the total WIP in a system. The CONWIP card limits the total WIP that is somewhere within the system and that means that the WIP is not controlled in between each workstation (Gastermann et al., 2012). Further, Gastermann et al. (2004) think it´s important to stress that the WIP still constrains the production system. The CONWIP system is a flexible system, a bottleneck in a production system can reduce the amount of cards and cards can be increased when throughput time increases (Marek et al., 2001). As Duranik et al. (2012) explain, CONWIP is a signal system that controls the maximum level of WIP and works as a "loop". A card in a container start of the production system and then released it again when an item is released from the system. A new entry of inventory is authorised and a "loop" has been created.

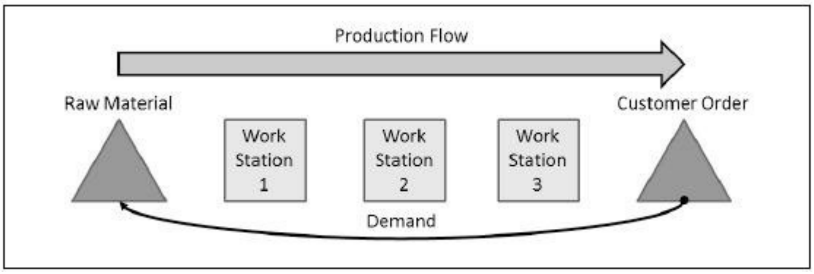

Fig. 2 A CONWIP pull-system (Gastermann et al., 2012 p. 559)

The CONWIP system is considered to be a Pull/Push tool, a *hybrid*, due to the "push" effect within the system (Gastermann et al., 2012). But still it is referred as a pull production tool (Prakash and Feng, 2012). The benefit of CONWIP, Segerstedt (2008) stresses, is that the system doesn´t restrict the WIP at each workstation it´s restricting the total WIP for the whole system. Prakash and Feng (2012) mean that the CONWIP system is easy to implement and understood by the blue collars, especially if the production consists of several product types. As Gastermann et al. (2012) point out, it´s a system that is simple to use and don´t need much management. Further, with one set of global cards the system can be more easily changed due to the restrictions of cards. Duranik et al. (2012).

5.3 A comparison between Kanban and CONWIP

There are similarities and differences between the kanban and CONWIP systems that are tools for supporting the JIT philosophy. Both system uses a WIP cap that restricts the WIP to an average maximum and prevent the WIP of expanding out of control (Hopp and Spearman, 2004). The systems uses signals to indicate a demand that start a “pull” reaction which Li (2011) means, will “pull” work through the production system. The signals and the controlled WIP is constraining the production system (Hopp and Spearman 2004). The kanban system uses signals at each workstation for controlling the WIP (Marek et al., 2001). By using a single controlled buffer between workstations it act as an in and out buffer for the down-stream and up-stream workstation (Kumar and Panneerselvam, 2007). The CONWIP system on the other hand uses a single set of global cards (Gastermann et al., 2012). The system act as a “loop”, when an item leaves the system a demand is created and a signal is sent that authorise new inventory entrance to the production process (Marek et al., 2001). Within the system a “push” reaction pushes material forward. Chosen buffer are situated somewhere within the system. Segerstedt (2008) points out that by not controlling each workstation, the system becomes less complicated and less management is needed. He also stresses that when kanban is restricting each buffer in between workstations, the CONWIP is instead constraining the whole system. Segerstedt (2008) explains that there are natural variations within a production system and the system’s ability to respond without disturbance is due to its flexibility. Variations can cause waiting time in a kanban system but this is prevented in a CONWIP system by the holistic view of the available WIP. If the WIP is lowered too much where there are variations, the flow constrains can starve or block the system (Pettersen and Segerstedt, 2009). Starving can be the case in a kanban system when a workstation becomes starved due to not being able to work because it´s waiting for the up-stream workstation. The working station can also be blocked and not being able to produce until down-stream workstation is available (Pettersen and Segerstedt, 2009). Hopp and Spearman (2004) stress that variability as inventory, capacity and time will act as a buffer in the production system and by reducing variability waste is reduced. Li (2011) agrees on the fact that the CONWIP system becomes more flexible by being able to control the WIP for the whole system instead of each work station which is the case with a kanban system.

Several articles describe simulations made to deepen the knowledge about kanban and CONWIP and which of them is superior. By a simulation comparing the two systems, Li (2011) showed that CONWIP was the superior system due to its capacity and robustness to meet the conditions in an MTO (make-to-order) production system with a supporting JIT practice. Gong et al. (2014) investigated decision making in production systems that uses kanban and CONWIP. Their conclusion by simulation was that the CONWIP system outperformed the kanban system by using less information exchange. They believe that this contribute to decreasing the amount of delays related to decision making. A simulation study was done by Pettersen and Segerstedt (2009). The study aimed to put forward the differences between kanban and CONWIP. The simulation showed the importance of having WIP controlled, if WIP increases there is a risk of increased variation. More inventory was needed in the kanban system in the simulation. They also stated that the disadvantage with kanban was its slow respond to changes in demand. A change require alterations of the amount of signals in the system. Marek et al. (2001) insist that the two pull system requires production flow that is stable. They consider that there is a risk of not being able to minimize WIP due to alternation of the systems needed by demand changes. To make a system respond to demand changes, Renna et al. (2013) investigated a computerized controller function based on evaluation of two moving average computations of the customer demand for kanban and CONWIP. Their simulation showed that the CONWIP system was superior. Renna et al. (2013) propose that production systems that use CONWIP can implement such a controller to make the system respond to changes in demand more efficiently. A simulation was made by Khojasteh-Ghamari (2009). The study shows that there are several parameters as amount of initial cards and initial inventories that has to be considered and will influence the performance of the system as well as the final result. With the same throughput rate in a tree shaped production system the CONWIP system had less average WIP then the kanban system. In a serial production line, the kanban system was sometimes performing better. Hence, the structure of the process, Khojasteh-Ghamari (2009) stresses is the dependable factor that decides which of the system is performing better than the other. Khojasteh-Ghamari (2009) and Li (2011) stresses that literature is giving contradictory information about which of kanban and CONWIP is the superior system. Segerstedt (2008) also mentions that the use of CONWIP practically is not proven as the kanban system and explains that there still are a lot of questions left to be studied.

6 Result

In this paper kanban and CONWIP systems have been studied to give a deeper understanding of the “pull” tools in a JIT production system. There are clear similarities as well as difference between these tools. Both system uses visual signals to control the low average WIP and to create a “pull” flow that responds to customer demand. The kanban system uses cards for the control of the average WIP between each workstation in the production system. CONWIP instead uses a single global set of cards to control the total average WIP within the system.

By comparing the two systems literature shows that there are contradictory opinions about which system is the superior. Some authors stress that kanban, by controlling WIP at each workstation, constrains the flow and by solving upcoming problems will make the system more efficient and resilient. Others believe that it can become a weakness due to starvation or blockage. Those in favour of the CONWIP system believes that the system is more flexible and easy to manage than kanban.

Several simulations show that the CONWIP system perform better than the kanban system, but sometimes kanban is the superior. Different parameters and the use of dependable factors can explain the differences in results. More research is needed to give a final answer to which system is superior of the other.

7 Discussion

In an unpredictable global market with demanding customer needs it becomes important to quickly be able to respond to market changes to stay competitive. By making continuously improvements each company strive towards a better competitive advantage. Marek et al. (2001) believe that by changing a traditional production system to a pull system, replacement within the system becomes driven by customer demand. A robust production system that is resilient is created and in such a system inventory is replaced when one has been consumed (Huang t al, 2014). Benefits as lead time reduction, better quality and cost reductions can be seen. The control of WIP and the creation of availability exactly when needed, is fundamental of a JIT production system. However, despite the benefits of JIT-production a lot of companies of today still uses a push production system or a combination of both. Situations are probably affecting the day-to-day work and to make changes are demanding in many ways.

This paper has focused on two JIT tools, kanban and CONWIP, that visualize the lowest average WIP and the production flow. Each tool has been described and a comparison has been carried out to lift forward similarities and differences between the systems and which of the systems is superior the other. The literature study shows that both kanban and CONWIP answer to the JIT philosophy by the use of visual signals to lower and control the average WIP, and by the creation of a “pull” flow. Replenishment becomes driven by actual customer demand instead of forecasts demand. To be able to lower WIP, the replacement must be made more often compared to a “push” flow. By reducing WIP, lead-time will be reduced which will shorten the time from customer order to delivery. By visualization of the customer demand, the system can fill each inventory buffer that been reduced by consumption.

The main difference between the systems is the different signal approach. The kanban system uses cards for each workstation to control the replenishment of WIP and the CONWIP system uses a single global set of cards that control all WIP within the production system. The different approach will of course affect the final result. Which system is superior the other is debated and the literature is contradictory in this area. Those in favour of kanban believe that the system is controlling each buffer in between stations and restricts the WIP from expanding out of control. Each workstation constrains the whole production system and will minimize the WIP. The opponents consider that there is a risk of starvation and blockage that will cause unnecessary restrictions of the flow. They mean by using CONWIP this can be avoided due to its flexibility of having an available buffer that can be found somewhere within the system. It´s also stressed that the CONWIP system is more easily changed and need less management than the kanban system. I believe it´s hard to make a general conclusion to which system is superior due to the fact that each production system is unique. A production system with stable conditions might benefit by the use of a kanban system, another production system with larger variations might benefit by the use of a CONWIP system.

Several simulations have been carried out to try to clarify the issue. Due to the authors limited knowledge of simulation methods the comparison between the simulations has been restricted. The studied simulations show that the CONWIP system is the superior, but sometimes the opposite result is achieved. The simulations are affected, as Khojasteh-Ghamari (2009) points out, of the amount of cards used and of the chosen production system configuration. What he describes is that if chosen parameters and dependable factors are different between simulations, the results will also be different. By simulations two different systems is compared and there´s a risk that one will benefit from the setting due to more favourable conditions. From the simulations results it´s hard to make a general conclusion of which system is superior, there are too many questions still to be answered. Though, in most simulations the CONWIP system was performing better with less WIP. With an overall view a JIT production system need a visible control mechanism for controlling WIP. Both kanban and CONWIP system provides this control mechanism. For time being, due to contradictory results, it´s up to each company to decide which of the two systems will fulfil their needs best.

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