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A SIMULATION-BASED LEAN PRODUCTION APPROACH AT A LOW-VOLUME PARTS MANUFACTURER WITH PART COMBINING

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ABSTRACT

Lean Production approach provides a framework to limit source of variability and to improve performance of production systems. If production units characterized by low-volume and part combining are considered, lean approach has to be tuned in order to provide the correct limitation of work-in-progress and the suitable sequencing of parts. In such a case, a discrete event simulation study is necessary to illustrate the control-element operations and indicate the applicability of the elements. A case study in the field of earth-moving machine is considered. A simulation study proved that the implementation of lean elements lead to a significant performance improvement.

1 INTRODUCTION

The principles of Lean Production have enabled organizations in the manufacturing sector to significantly improve their competitiveness. Indeed, the application of Lean principles, derived from the Toyota Production System, allowed many organizations to simultaneously improve productivity, quality and customer service (Portioli Staudacher and Tantardini 2012).

The recent literature on production control in Lean production environments has considered the significance of the characteristics of the production environment (Riezebos et al. 2009). The ConWIP (constant work in process) system (Framinan et al. 2003) is a card mechanism in which all jobs following the same production sequence may be different as long as the follow the same routing. Make-to-stock environments may use product-specific cards, such as Kanban. The main difference with Kanban is that ConWIP does not use small intermediate stocks in production or the supply chain. Most ConWIP studies have considered the design of systems in a make-to-stock setting (Framinan et al. 2003). 'Pull' systems became extremely demanded due to the increased use of Lean Production, which aims to minimize waste (González-R et al. 2011). Specifically, high throughput and work in progress are considered as waste (Riezebos et al. 2009). 'Pull' systems lead to reduce throughput by limiting the amount of work-in-progress on the shop floor. If the WIP is below a critical threshold, throughput is too small and the system is not able to fulfill the necessary demand. Consequently, work-in-progress has a key function in leveling production output. In some cases, 'pull' systems aim to obtain the minimum WIP, in others, they aim to keep the WIP as smooth as possible, while others just adopt a maximum threshold, not to be exceeded.

Moreover, in the production system, if the WIP is ineffectively located the production rate is low. For example, a bottleneck causes some machines are busy while others are idle. Therefore, it is important, in 'pull' systems, the location of the WIP within the production system.

In this production contest, the lean approach provides firms with a framework and a set of principles to identify and eliminate unnecessary sources of variability and to improve the performance of their production systems (Hopp and Spearman 2004). Consequently many companies are interested in implementing lean control principles, such as 'pull' and takt time control (Karrer 2012). The key to the effectiveness of 'pull'

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systems is that they explicitly limit the amount of WIP that can be in a system. Takt time control is adopted to efficiently allocate production throughout (Miltenburg 2001). The constraints imposed by these lean manufacturing principles simplify the control of the production system and provide motivation to reduce the variability in the production system.

Hopp and Spearman (2000) provided a general introduction to the ConWIP system of material control. Framinan et al. (2003) provided several extensions and variants of ConWIP. The important factors are:

- the authorization mechanism,
- the type and number of items in WIP,
- and the location of the WIP.

According to the definition of Hopp and Spearman (2004), ConWIP is a 'pull' system. ConWIP adopts both physical and virtual authorization procedure. The physical method, which may use either cards or containers, provides authority to the operators for new order releases. In a ConWIP system the choice of items to produce is determined by the virtual method. The physical system only indicates that a new order may be released without indicating the order set from which to choose. Instead, the sequencing and scheduling module determines which orders will be released in the system; this may significantly affect the timing and balancing capability of the whole system.

Kanban and similar logistics systems, which are simple, robust and strictly limit WIP are very successful. These systems were much more successful than early automation and computerized planning and control approaches (Keller 1989). However, there have since been many successful developments in both automation and computer-aided production management. Companies focusing only to the limited choices advocated by Toyota production system and Kanban system would have missed important opportunities to improve their competitiveness. For such a reason, the correct use of Lean principles relies on the possibility to tune their application on the shop floor. In this way, a correct integration with other techniques, for example discrete event simulation, is able to efficiently exploit their benefits. Bokhorst and Slomp (2010) proposed an interesting approach to integrate lean production control adopting the discrete event simulation tool at a High-Variety, Low-Volume Parts Manufacturer.

Historically, 'pull' and takt time lean control principles have mainly been applied in high-volume flow environments in which jobs move through the production system in one direction along a limited number of identifiable routings.

Instead, this paper focuses on the correct implementation of lean control elements for a make-to-order (MTO) job shop that manufactures different part types in very small batches (around 10 parts per shift) having long processing times (more than one hour). Initially, the company suffered from large amounts of WIP, and its job flow-times were excessive and variable. Then, a very low level of WIP was adopted in order to drastically reduce flow-time but a scarce productivity was obtained. Finally, our approach tuned the right WIP level and selected the right Lean control policy in order to both meet customer demand and reduce cost.

Determining and tailoring optimal control policy is a difficult task. The objective of this work consists in supporting production system managers to customize a suitable production control strategy. A real case study demonstrates the evidence-based applicability of the presented approach.

The paper is organized as follows. In Section 2, the problem statement is introduced in detail. In Section 3, our discrete event simulation approach to solve the problem is presented. In Section 4, the results of the application of the approach of this study are reported and compared. Finally, in Section 5, some conclusions are drawn.

2 PROBLEM STATEMENT

The general problem is to find that optimal WIP level w and the best lean control principle (ConWIP, FIFO, Takt, ...), in order to meet the required productivity level of a job shop and maximizing performance

Table 1: Parameters and Variables.

Symbol	Description
M	number of part types
N	maximum number of part type operations
L	number of resources
j	part type index, $j = 1, \dots, M$
n_j	number of operations for part type j
i	operation index, $i = 1, \dots, N$
k	resource index, $k = 1, \dots, L$
r_{ji}	resource for operation i and part type j
p_{ji}	duration for operation i and part type j
c_k	number of parts to be simultaneously processed at resource k
Ψ_j	required system throughput for part type j
w	work-in-progress level
$\overline{\Psi_j}(w)$	average system throughput for part type j
$\overline{f_j}(w)$	average flow-time for part type j

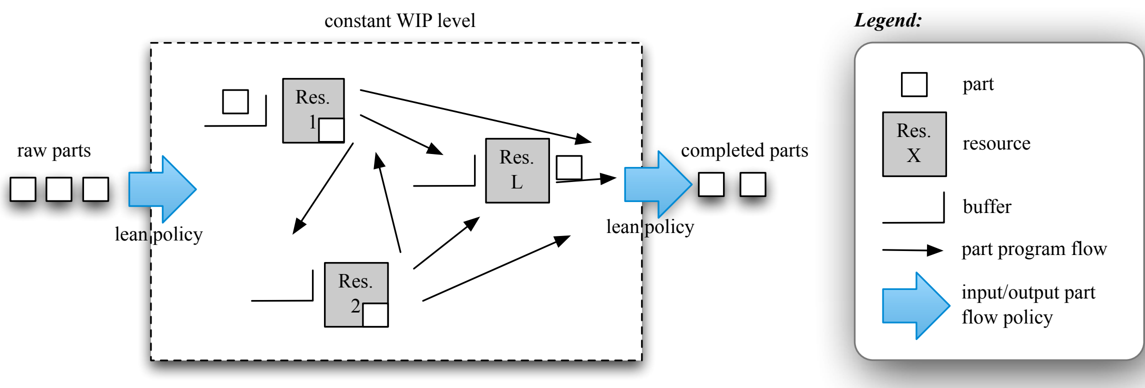

Figure 1: System layout.

indicators. In the following, we present the general problem and introduce the formalism. Parameters and variables are reported in Table 1. The system layout is described in Figure 1.

Considering a given part type j, the corresponding part program is made of n_j operations ($n_j \leq N$). Each operation is performed on a given resource r_{ji} and has an assigned duration p_{ji}. A resource k can be used in the same part program many times. A specific characteristic of our system is the following: a resource exists $\bar{r}$ that simultaneously process a couple of identical parts by combining them. It is important to note that, after the resource $\bar{r}$ processing, the two combined parts continue together the processing and the control policy should decide whether the WIP has decreased (due to the combining) or not and consequently allowing a new part enters the system to maintain constant the WIP level.

A required production rate Ψ_j is established for each part type j. Because of the WIP level constraint, only w different parts are at various stages of the production process. Moreover, a given lean policy can be adopted in the system.

Assigned w and the lean control principle, the average value of the production rate $\overline{\Psi_j}(w)$and flow-time $\overline{f_j}(w)$ for each part type j are assessed by using a discrete event simulation model.

The objective of the study consists in determining the WIP level optimal value in order to satisfy the production rate requirement for each part type and minimize the flow-time for all the part types.

Informally, assigned the lean policy, the optimization problem can be described as in (1)-(3).

$$\begin{aligned} min \quad & \overline{f_j}(w) && (1)\\ \overline{\psi_j}(w) \quad & \leq \Psi_j \quad \forall j = 1,\ldots,M && (2)\\ w \quad & \text{int} && (3)\end{aligned}$$

3 PROPOSED APPROACH

Considering the above mentioned problem, we selected different elements of lean control for the ConWIP general approach. In particular, the following options are analyzed:

- **FIFO sequencing:** to control the order of departing jobs. A new job can enter the system only when the oldest job in the system exists. If jobs complete ahead of the FIFO sequence, no new jobs are released until the oldest job has finished, thus reducing the real WIP. When the oldest job exists the correct WIP is established.
- **Takt time**: to control the timing of departing jobs. A job will only enter at a takt moment; a moment in time with intervals of at least the minimum possible takt time. At that moment, a job leaves the system and a new job can be released, the new job has to wait until the next takt moment to enter the system. The minimum possible takt time is computed assuming the full resource utilization.
- **Elemental WIP**: to control the effective number of jobs in the WIP. If the option is enabled, when two parts are combined and a single job is created, a new one must enter the system to have the same WIP. Therefore, when the two-part job exists from the system, only one new job is released. Instead, if this option is disabled, even if two parts are combined and treated as one single entity, such single entity is considered twice in the WIP computation. Consequently, when entity exits from the system, two new jobs are released to maintain a constant WIP level.

Such options are combined in a lean control system. ConWIP is always adopted to limit the number of jobs. FIFO focuses on the oldest jobs in the system in order to reduce the variability in throughput values. Takt time supports a regular flow of jobs according to the customer demand. Elemental WIP determines how to deal with combined parts in terms of WIP calculus.

A discrete event simulation model has been designed with Simio (Sturrock and Pegden 2011). The developed model is able to reproduce the behavior described in the previous section problem, in particular the system reported in Figure 1. Moreover, the three options (above described), determining the principles of lean control, have been implemented and can be activated. In Figure 2 it is possible to analyze the shop floor model designed in Simio. Raw parts are stored at the 'Cutting' stage, after entering the system, parts are processed by resources 'CNC_Machine_A' and 'Assembly_A' depending on the particular part type. After, parts are pairwise combined in the resource 'Welding'. Finally, in 'CNC_Machine_B' and 'Assembly_B' resources, the last set of operations is performed depending on the part type. The resource 'Painting' is that one pulling parts from the analyzed shop floor and it is represented only for reference purpose.

The ConWIP policy is straightforwardly implemented by a resource WIP having initial capacity equal to w. Such a resource is seized after the entity creation ('Cutting' stage) and released when the entity enters the 'Painting' stage.

In the following, we describe only the algorithm implemented in the Simio model in order to obtain the three options of the lean control principles.

Algorithm 1 describes the 'FIFO sequencing' option and is executed when the entity enters the 'Painting' stage. If the FIFO option is enabled, the WIP resource is not automatically released when entity completes

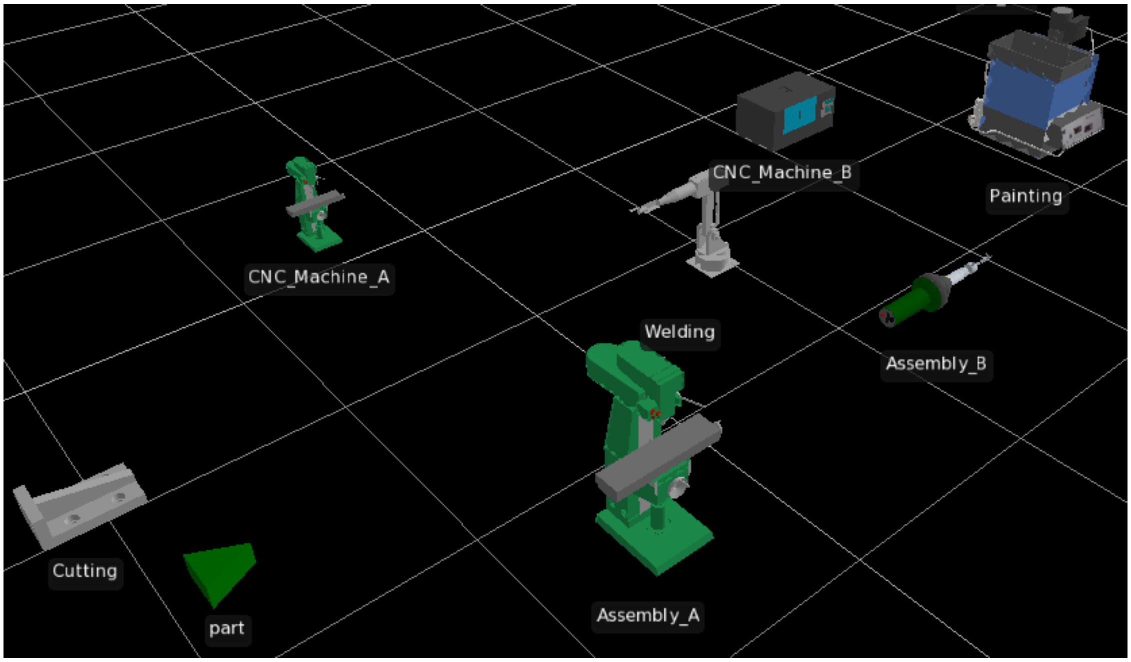

Figure 2: Simio simulation model (facility layout).

the processing. Indeed, as long as the exited entity is not the oldest, the resource WIP is not released and the variable $Credit$ counts such occurrences. Then, when the oldest part completes the processing, all the previous releasing, together with the current one, are performed ($Credit+1$).

Algorithm 2 illustrates the ‘takt time’ option and is executed after the entity has successfully seized the resource WIP. Takt time is represented by τ. If the Takt time option is enabled, the entity has to seize also the resource $Takt$. Periodically, every τ time units, such a resource is activated only for a negligible period of time (ε). Only one entity at time can seize the resource because of the ‘Delay ε’ instruction at line 2.

‘Elemental WIP’ option is implemented by releasing the resource WIP at a particular point in the model. If this option is enabled, one unit of resource WIP is released after entity reaches the ‘Welding’ stage and another one when arriving at ‘Painting’ stage. Instead, if disabled, 2 units of resource WIP are only released when the entity arrives at the ‘Painting’ stage.

Algorithm 1 FIFO sequencing

Require: Global variable $Credit$ initially 0
Require: Resource WIP having initial capacity w

```
if Current entity is the oldest then
    Release Credit + 1 units from WIP
    Credit ← 0
else
    Credit ← Credit + 1
end if
```

Algorithm 2 Takt time

Require: Takt time τ
Require: A small value time $\varepsilon \gtrsim 0$ (ex: $\varepsilon = 0.0001$ min)
Require: Resource *Takt* (Capacity: 1; Failure: Calendar based; Uptime between repair: ε, Time to repair $\tau - \varepsilon$)
1: Seize resource *Takt*
2: Delay ε
3: Release resource *Takt*.

Table 2: Experimental campaign scenarios.

Scenario	FIFO seq	Takt time	Elemental WIP
0-0-0	Off	Off	Off
0-0-1	Off	Off	On
0-1-0	Off	On	Off
0-1-1	Off	On	On
1-0-0	On	Off	Off
1-0-1	On	Off	On
1-1-0	On	On	Off
1-1-1	On	On	On

4 CASE STUDY

In this section, we analyze the performance of the different options introduced in the previous sections. In particular, different experimental campaigns have been developed as reported in Table 2. Considering the base problem in which 'ConWIP' is adopted, eight different scenarios have been analyzed considering the presence/absence for the 3 options.

A numerical case derived from a real industrial test case in the earth-moving machine field is adopted. The problem was solved using the discrete event simulation model reported in the previous section. The programming was done using Simio ver 3.54.

The real industrial test case is described in Table 3, in terms of resources, and Table 4, considering the part type operations. The number of part types is $M = 2$ and the number of resources is $L = 5$. In particular, the first part program is made of $n_1 = 7$ operations whereas the second one is processed with $n_2 = 8$ operations. Finally, the required system throughput is $\Psi_1 + \Psi_2 = 20$ parts/day (two 8h shifts per day). The part mix is 70% part type 1 and 30% part type 2.

Results for the experimental campaign are computed for each scenario in Table 2 by varying the WIP level w. We assessed simulation length is 256 h, whereas warm-up period duration is 32 h. In Table 5 and Figure 3 average throughput values are reported, whereas in Table 6, Figure 4, Table 7 and Figure 5 the average flow-time values are showed for part type 1 and part type 2.

We first focus on productivity analysis referring to Table 5 and Figure 3. Since the required throughput is 20 parts/day, the basic ConWIP rule (scenario 0-0-0) allows to reach such results when WIP level is $w = 7$

Table 3: Resources of the industrial test case.

r	Name	c_r
1	CNC_Machine_A	1
2	Assembly_A	1
3	Welding	2
4	CNC_Machine_B	1
5	Assembly_B	1

Table 4: Part type operations of the industrial test case.

j	i	r_{ji}	p_{ji} (min)
1	1	1	10
1	2	2	24
1	3	1	7
1	4	3	33
1	5	4	15
1	6	5	26
1	7	4	9
2	1	1	8
2	2	2	16
2	3	1	8
2	4	2	9
2	5	3	32
2	6	5	15
2	7	4	23
2	8	5	13

(throughput is 20.8 part/day). If 'FIFO sequencing' option or 'takt time' option are enabled (scenarios 1-0-0, 0-1-0, 1-1-0), the productivity decreases as reported in Figure 3. 'FIFO sequencing' option leads to a lower productivity than 'takt time' option. Note that if both the two options are enabled, we report the minimum productivity. Instead if 'Elemental WIP' is enabled (scenario 0-0-1) starting from the basic ConWIP rule, we obtain the maximum productivity. This because 'Elemental WIP' option increases the real WIP value in the system: a new job enters the system as soon as two jobs are combined. Also in this case, if 'FIFO sequencing' option or 'takt time' option are enabled (scenarios 1-0-1, 0-1-1, 1-1-1), throughput decreases (see dotted lines in Figure 3).

Then, we analyze the flow-time values referring to Table 6, Figure 4, Table 7 and Figure 5. The U-shaped form in Figure 4 and Figure 5 is caused by the difficulty to combine two parts of the same type when WIP level is low. Indeed, a part has to wait another one arrives at the combining stage to be processed and combined. In particular, such a waiting time is greater for part type 2 than part type 1 because, in the production mix, part type 2 frequency (30%) is lower than part type 1 (70%). When WIP level increases, we verify that flow-time increases. Starting from the basic 'ConWIP' scenario 0-0-0, if 'FIFO sequencing' option or 'takt time' option are enabled (scenarios 1-0-0, 0-1-0, 1-1-0), the flow-time decreases as reported in Table 6 and Table 7. Instead, if only 'Elemental WIP' option is enabled, flow-time increases because of the higher real WIP level (for each color, compare dotted and solid lines in Figure 4 and Figure 5).

Considering the optimization problem described in Section 2, for each scenario it is possible to select the WIP level having the required throughput and the minimum flow-time. For example, in the basic 'ConWIP' scenario (0-0-0), the best WIP level value is $w = 7$, having a global throughput $\overline{\psi_1}(7) + \overline{\psi_2}(7) = 20.8 (> 20)$ parts/day (see Table 5) and flow-time values $\overline{f_1}(7) = 2.8$ h and $\overline{f_2}(7) = 3.6$ h.

Considering all the scenarios, the best one is 0-1-1. Indeed, adopting $w = 5$, it is possible a get global throughput $\overline{\psi_1}(5) + \overline{\psi_2}(5) = 21.6$ parts/day and the minimum flow-time values $\overline{f_1}(5) = 2.6$ h and $\overline{f_2}(5) = 3.5$ h. Consequently, the best solution adopts the lean policy 'ConWIP' with WIP level $w = 5$, along with the 'takt time' and 'Elemental WIP' options enabled (scenario 0-1-1).

Table 5: Scenario productivity of the industrial test case.

	Scenario productivity (part/day)							
WIP	0-0-0	0-0-1	0-1-0	0-1-1	1-0-0	1-0-1	1-1-0	1-1-1
4	10.1	17.6	9.5	16.3	10.1	16.1	9.5	15.0
5	14.0	24.1	13.2	21.6	14.0	19.9	13.2	18.9
6	17.1	28.1	16.1	26.2	16.8	22.7	15.9	22.1
7	20.8	28.2	19.7	28.2	19.7	24.9	18.8	24.8
8	23.7	28.2	22.5	28.2	21.9	26.4	21.1	26.6
9	26.8	28.2	25.8	28.2	24.0	27.3	23.3	27.8
10	28.2	28.2	28.2	28.2	25.5	27.8	25.2	28.2
11	28.2	28.2	28.2	28.2	26.7	28.1	26.8	28.2
12	28.2	28.2	28.2	28.2	27.4	28.2	27.8	28.2
13	28.2	28.2	28.2	28.2	28.0	28.2	28.2	28.2
14	28.2	28.2	28.2	28.2	28.2	28.2	28.2	28.2
15	28.2	28.2	28.2	28.2	28.2	28.2	28.2	28.2
20	28.2	28.2	28.2	28.2	28.2	28.2	28.2	28.2
25	28.2	28.2	28.2	28.2	28.2	28.2	28.2	28.2

Table 6: Scenario part type 1 flow-time of the industrial test case.

	Scenario part type 1 flow-time (h)							
WIP	0-0-0	0-0-1	0-1-0	0-1-1	1-0-0	1-0-1	1-1-0	1-1-1
4	3.5	3.0	3.4	2.8	3.5	3.0	3.4	2.9
5	3.1	2.8	3.0	2.6	3.1	3.0	3.0	2.8
6	3.0	2.8	2.9	2.6	3.0	3.0	2.9	2.7
7	2.8	3.1	2.7	2.7	2.9	3.1	2.8	2.7
8	2.8	3.4	2.7	3.0	3.0	3.2	2.7	2.7
9	2.8	3.6	2.6	3.2	3.0	3.4	2.7	2.7
10	2.9	3.9	2.7	3.5	3.1	3.6	2.7	2.7
11	3.2	4.2	2.9	3.8	3.2	3.9	2.6	2.9
12	3.5	4.5	3.2	4.1	3.4	4.1	2.7	2.9
13	3.8	4.8	3.5	4.4	3.6	4.4	2.7	3.2
14	4.1	5.1	3.8	4.7	3.8	4.7	2.8	3.5
15	4.4	5.3	4.1	4.9	4.1	5.0	2.9	3.5
20	5.8	6.8	5.5	6.4	5.5	6.3	4.0	4.4
25	7.2	8.2	6.9	7.8	6.9	7.7	4.8	5.5

Table 7: Scenario part type 2 flow-time of the industrial test case.

	Scenario part type 2 flow-time (h)							
WIP	0-0-0	0-0-1	0-1-0	0-1-1	1-0-0	1-0-1	1-1-0	1-1-1
4	5.2	4.1	5.3	4.0	5.2	4.2	5.3	4.1
5	4.2	3.5	4.3	3.5	4.2	3.8	4.3	3.7
6	4.0	3.4	3.9	3.3	4.0	3.8	3.9	3.5
7	3.6	3.7	3.5	3.3	3.8	3.8	3.6	3.4
8	3.5	4.0	3.5	3.6	3.7	3.9	3.5	3.3
9	3.4	4.2	3.3	3.8	3.7	4.0	3.4	3.3
10	3.5	4.5	3.3	4.1	3.8	4.2	3.3	3.3
11	3.8	4.8	3.5	4.4	3.9	4.5	3.3	3.5
12	4.1	5.1	3.8	4.7	4.0	4.7	3.3	3.5
13	4.4	5.4	4.1	5.0	4.2	5.0	3.3	3.8
14	4.7	5.7	4.4	5.3	4.4	5.2	3.4	4.1
15	5.0	5.9	4.7	5.5	4.7	5.5	3.5	4.1
20	6.4	7.4	6.1	7.0	6.0	6.9	4.6	5.0
25	7.8	8.8	7.5	8.4	7.5	8.4	5.4	6.1

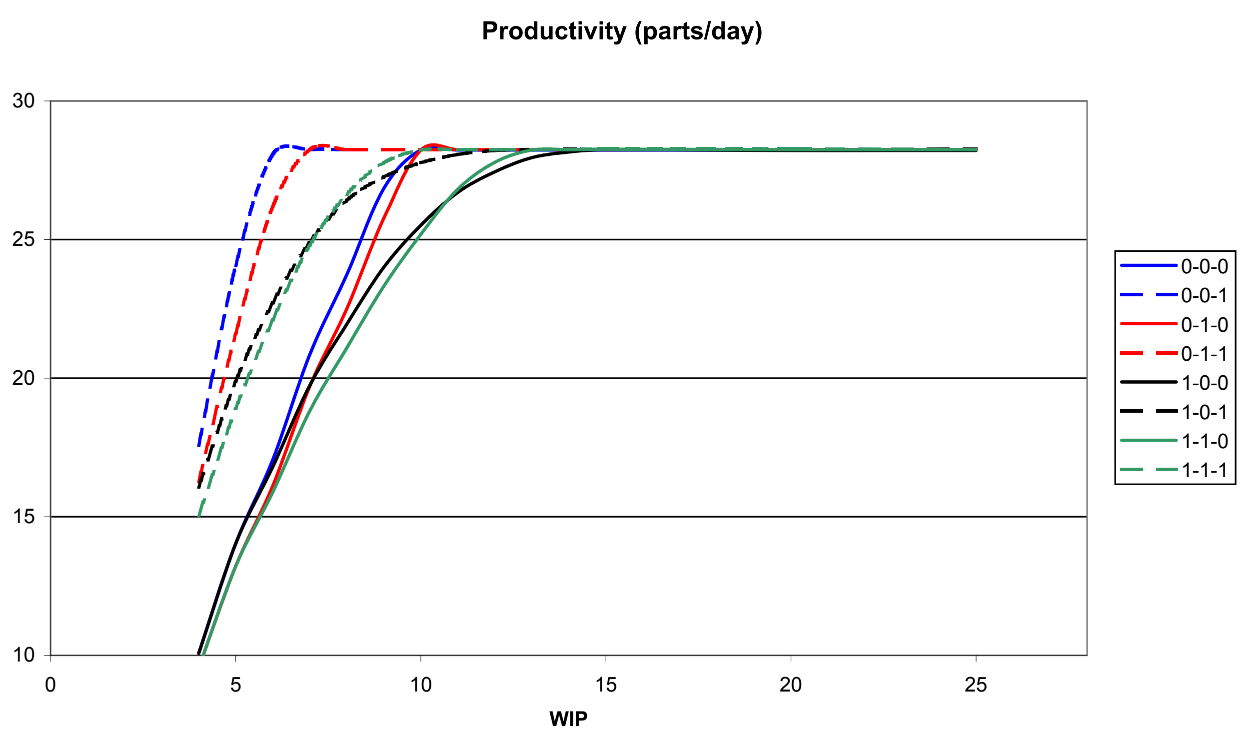

Figure 3: Scenario productivity of the industrial test case.

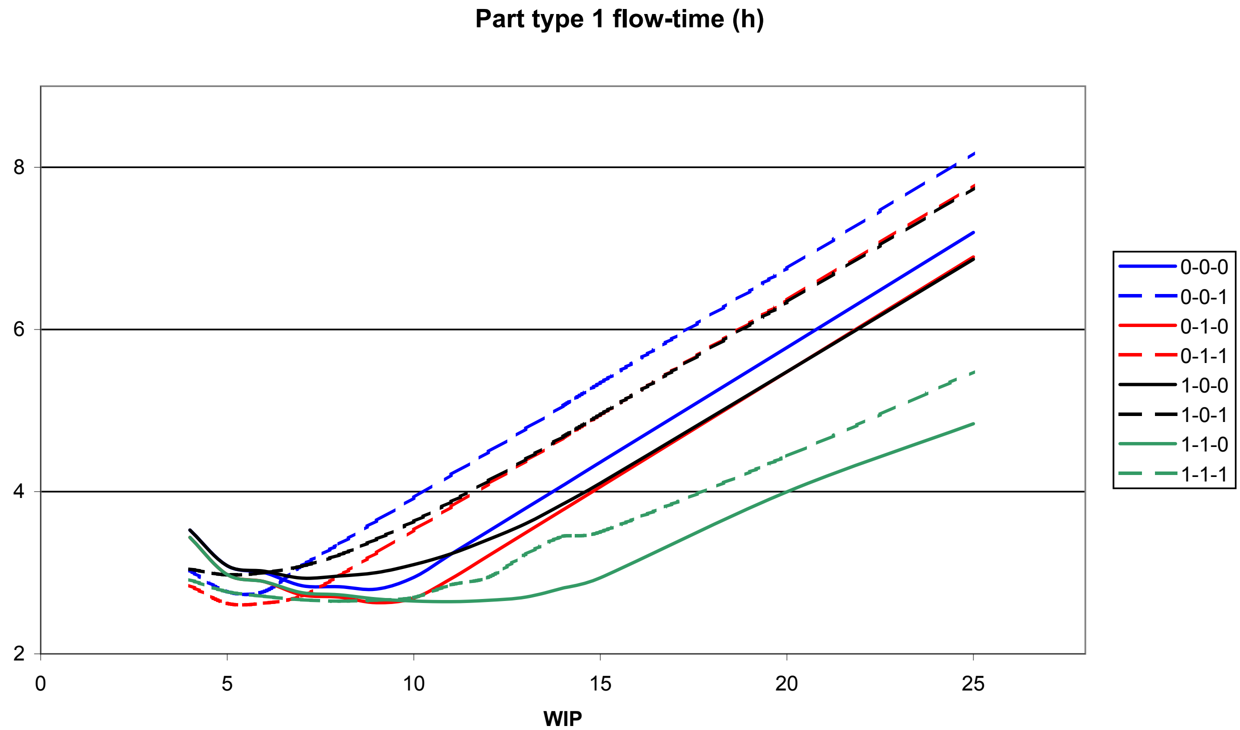

Figure 4: Scenario part type 1 flow-time of the industrial test case.

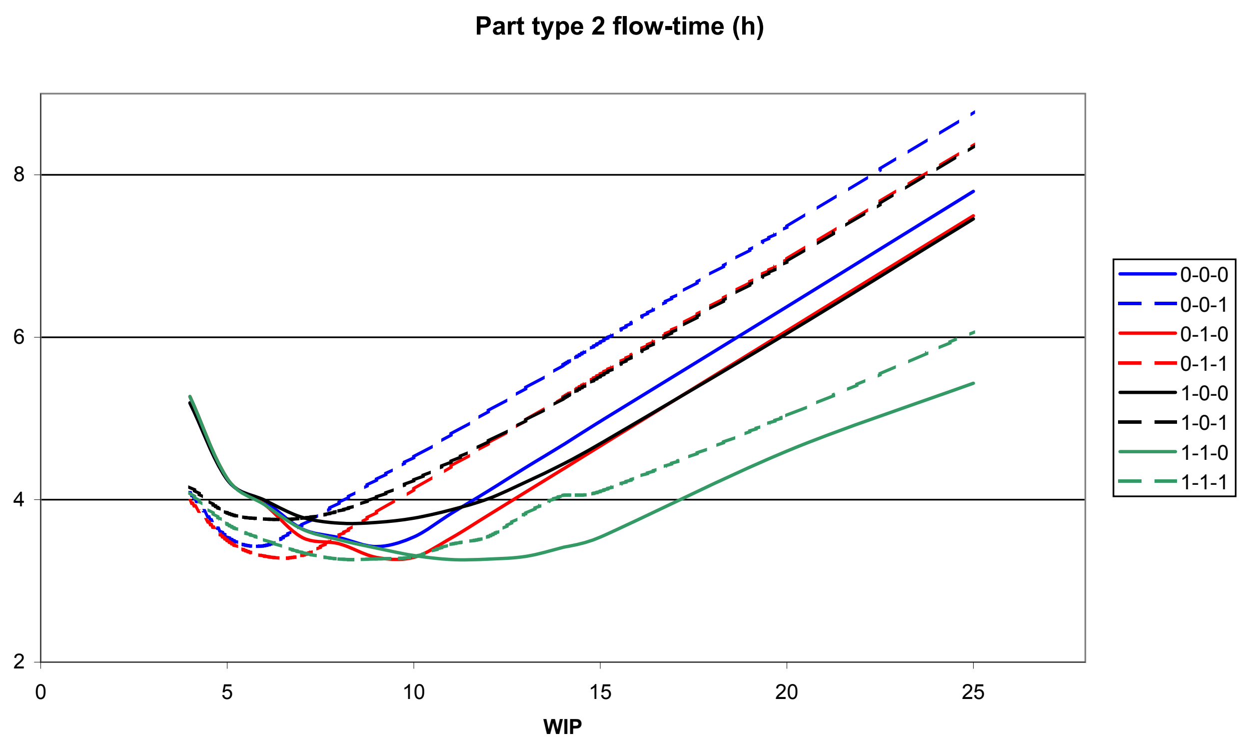

Figure 5: Scenario part type 2 flow-time of the industrial test case.

5 CONCLUSION

In this paper, we have shown how elements of lean control systems can be used to limit sources of variability and to improve performance. These control elements usually include the ConWIP mechanism to limit and control the amount of WIP, FIFO sequencing to control the order of departing jobs, and takt time to control the timing of departing jobs. In our case, we designed an additional control element to deal with the part combining mechanism present in our shop floor architecture. Our simulation study shows how tuning and selecting the best control elements. Therefore, it seems likely this approach can be successfully adopted in similar industrial environments.

REFERENCES

Bokhorst, J. A. C., and J. Slomp. 2010, May. "Lean Production Control at a High-Variety, Low-Volume Parts Manufacturer". *Interfaces* 40 (4): 303–312.

Framinan, J. M., P. L. González, and R. Ruiz-Usano. 2003, April. "The CONWIP production control system: Review and research issues". *Production Planning & Control* 14 (3): 255–265.

González-R, P. L., J. M. Framinan, and H. Pierreval. 2011, April. "Token-based pull production control systems: an introductory overview". *Journal of Intelligent Manufacturing* 23 (1): 5–22.

Hopp, W., and M. Spearman. 2000. *Factory Physics: Foundations of Manufacturing Management*. McGraw-Hill Higher Education.

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

Karrer, C. 2012. *Engineering Production Control Strategies: A Guide to Tailor Strategies That Unite the Merits of Push and Pull*. Springer.

Keller, M. 1989. *The Rude Awakening*. William Morrow, New York.

Miltenburg, J. 2001. "One-piece flow manufacturing on U-shaped production lines: a tutorial". *IIE Transactions* 33:303–321.

Portioli Staudacher, A., and M. Tantardini. 2012, January. "Lean implementation in nonrepetitive companies: a survey and analysis". *International Journal of Services and Operations Management* 11 (4): 385–406.

Riezebos, J., W. Klingenberg, and C. Hicks. 2009, May. "Lean Production and information technology: Connection or contradiction?". *Computers in Industry* 60 (4): 237–247.

Sturrock, D. T., and C. D. Pegden. 2011, December. "Recent innovations in Simio". In *Proceedings of the 2011 Winter Simulation Conference*, edited by S. Jain, R. R. Creasey, J. Himmelspach, K. P. White, and M. Fu, 52–62. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

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