ONE PIECE FLOW – CARAVANS, DEEPER RECOGNITION

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Abstract:

The aim of this article is to examine the above mentioned strategy by simulation using data of a particular production sector.
An identical model is created as a common strategy employing same production capacities: appliances, production period, and quantity of workers. The model is completed by a performance matrix of individual workers' skills. Significant difference is also in the management logics of directing workers and material flow in comparison with classical strategy.

The first article endeavours to map capacity of the strategy to deal with influence of human factor. Main focus was on constrained localities created by a slower worker in training.

We follows the experiment adverting the strategy performance respective different process load by product type variants, where the effect of Moving constrained localities might occur. Part of this experiment is thus also the perspective of the production batch volume.

INTRODUCTION

Growing attention is drawn to more effective management and utilization of modern technologies. It is right the effective application and management that enables to survive in the period of economic crises. One of the fairly little used goals is planning, control and distribution of labor on a foreman level or team leader level, associated is manly the use of suitable work distribution. Adequate strategy should standardize the processes of worker distribution. It should minimize the decision making of the managing authority and enable delegation of competences. Except traditional out-tacting, where the worker is steadily assigned a position/ positions we should not omit also further strategies that might increase process effectivity – e.g. One pieces flow caravans or Bucket brigades

Generally accessible information about the worker distribution strategies with U-cells are often limited to essential principles. There is very low awareness of real behaviour when applying these strategies.

In this article we will concentrate on the deeper understanding of the One piece flow – caravans strategy. In order to obtain new knowledge we are to use Witness simulation strategy.

Generally available information, on this strategy mention the worker distribution within material flow process – one piece flow, as implies. The title Caravans directly reflects the principle of workers distribution. Each worker passes with one product the whole process one by one, just like a caravan of camels walking through a dessert. Subsequently returning for next part while keeping its sequence order; thus equally loading all workers.

This strategy is considered simple organization. It delegates the distribution problem directly on workers and thus the team becomes autonomous. Its low application in practice is

due to scarce of multi-skill workers managing complete processes and necessary to move from workplace to workplace.

1. PROCESS STRAINING BY HUMAN FACTOR

Within levelling (balancing U-Cell) the distribution labor operation on individual workplaces is carried out with aim of balancing time and physical load on individual operations. It should result in absolutely harmonic process respective technological procedure, standardized labor and appropriate logistic system of component supply compared to other variants.

Capacities of One pieces flow caravans strategy are examined on a real process model (Fig. 1). It applies to reconditioning of electronic devices of an older model line. The validity of the models has been executed in cooperation with working practice. In the experiment parameters from real environment has been applied. It is a process divided to 12 manual workplaces attended by 3 to 12 operators depending on the volume of supply of parts for overhaul.

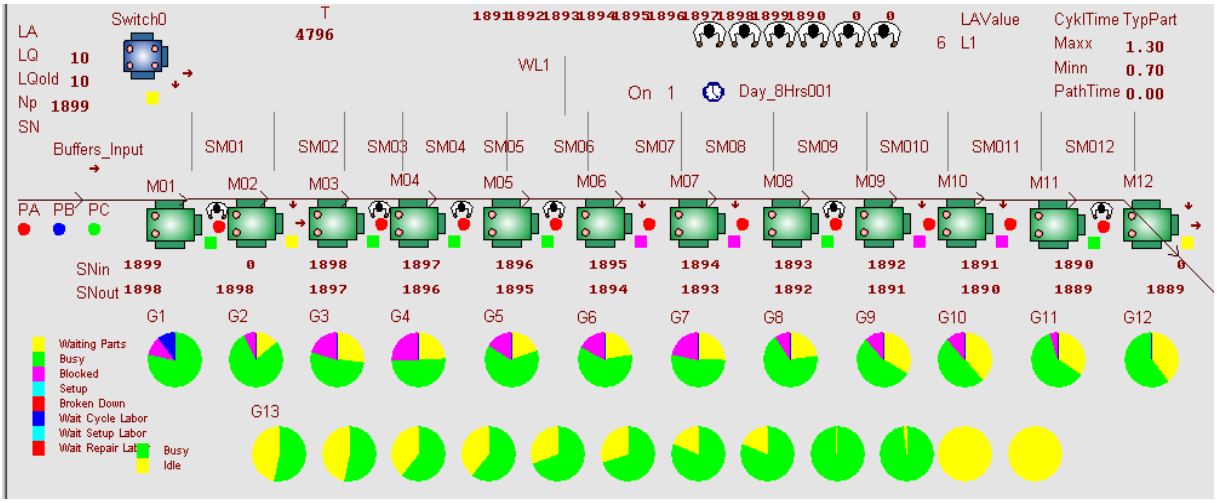

Figure 1 *Witness: Simulation model - One piece flow - Caravans*

1.1 Simulation – basic experiment

First step is a simulation cycle with parameters resulting from analytic solution. These parameters are constant time clusters and balanced skill matrix. A sole product variant has been processed within this experiment. The evaluation marker is a quantity of manufactured products in a time period of 4800 min corresponding to 10 eight-hour shifts.

Based on the results of the firs step of the experiment (Table No.1) we define second comparison base for the following phases. This base shall be the production of 2539pcs/10 shifts, representing the basis (100%) to express production in percents.

Table No. 1 Assembled parts – experiment No.1 step 1

One_piece_flow_-_Caravans	Assembled	Assemb. %
Production	2539	100%

From the Table (No.2) might be apparent organization idle times of all 10 engaged workers. In this case the load of individual workers is even. Idle times occur only when stating up production from zero work-in-process.

Table No. 2 Blocking of individual workers for experiment No.1 phase1

Blocking of individual workers for experiment No.1 step1.										
Labor	1	2	3	4	5	6	7	8	9	10
Blocked%	6.90	6.94	6.98	7.02	7.06	7.10	7.14	7.18	7.21	7.23

Indispensable is also strategy requirement that all workers must manage the complete process. This aspect imitates application of this strategy for more exacting and longer processes.

1.2 Simulation – manual work experiment

Within the following phases was the strategy burdened by stochastic effects. Initially a fluctuant manual work time has been applied on individual operations – experiment No.1 phase 2. The distinction has been simulated by [Witness] TRIANGLE distribution (0.8*Tac,Tac,1.2*Tac), where Tac are process operation times respective standards (norm).
Comparing results of experiment No. 1 phase 2 with stochastic effects and No. 1 without stochastic effects we arrive to the following postulates:
Based on comparison of Tables (Table No. 1 and Table No. 3) we may declare that already this stochastic influences productivity- Strategy markers 6.6 % decrease.

Table No. 3 Assembled parts and work-in-process – experiment No.1 phase 2

One_piece_flow_-_Caravans	Assembled	Assemb. %
Production	2372	93.4%

Comparing Tables (Table No. 2 and Table No. 4) we may state increased worker blockage by approx. 6%.

Table No. 4 Blockage of workers – experiment No.1 step 2

Blocking of individual workers for experiment No.1 step2.										
Labor	1	2	3	4	5	6	7	8	9	10
Blocked%	12.87	13.32	13.00	12.80	13.05	13.09	13.02	13.25	13.16	13.57

1.3 Simulation – experiment operator training

At the third experiment type, the strategies were burdened by fluctuant manual labor time on individual operations similar to experiment No.1 step 2 but another human factor was added represented by operator-skill factor. Worker orientation has been in a model situation realized by completion of time standard (Table No. 5). Here it was also based on the submitter's information.

In the referential practice process the real capability of members of actual operation team to complete efficiency standard oscillate in the range of approx. 60% to 120%. Keeping the possibility to compare individual experiments, we select the values in the extent from 70% to 130%. By an appropriate selection we reach 100% performance as in previous experiments. In order to retain legibility of the results of the experiment the idealized workers manage all the workplaces on the same skill level.

Table 5 Worker-skill matrix – experiment No.1 step 3

Labor	1	2	3	4	5	6	7	8	9	10	11	12
1	130%	130%	130%	130%	130%	130%	130%	130%	130%	130%	130%	130%
2	130%	130%	130%	130%	130%	130%	130%	130%	130%	130%	130%	130%
3	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%
4	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%
5	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
6	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
7	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%
8	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%
9	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%
10	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%

Comparing the results of experiment No 1, phase 2 with experiment No 1. faze 3 we come to flowing conclusion: Exp. 1/3 (Table 6) shows considerable strategy productivity fall to 74.4% compared to 93.4% productivity from exp. no .1/2.

Table 6 Assembled parts and work-in-process – experiment No.1 phase 3

Strategy	Assembled	Assemble %
OPF Caravans	1889	74.4%

Following result (Table7) refer to complexity of utilization of human potential. A considerable blockage and thus inefficiency of human capacity occurs – that is at the higher efficiency (labor 1 – 4), but also at standard workers (labor 5 a 6). It is simultaneously barrier dramatically limiting efficiency rating of the worker.

Table 7 Blockage of Workers – experiment No.1 phase 3

Blocking of individual workers for experiment No.1 step 3.										
Labor	1	2	3	4	5	6	7	8	9	10
Blocked%	46.91	46.73	39.69	39.60	30.99	30.64	18.56	18.94	0.79	1.70

1.4 Outcome of the Experiment

Based on this experiment is apparent that statistic simplification used in within analytic methods brings into this strategy a significant lap. Conduct of the real system of this type might and usually is sensitive to constrained localities also in the form of a below standard worker. Evidently, efficiency fall of the system might be considerable, ordinary tens of percent.

2. PROCESS BURDENING BY PRODUCTION MIX

Aim of this experiment is to refer to complexity of falling process efficiency due to the increased number of variants. Also the fair modifications of products (preparation for accessories) cause processing time increase on selected workplaces. Product flow within the process falls.

Producing variable variants we shall assume to find also various CL (limitations).Changing the variant also causes a transfer of CL to a different workplace, in such case we again speak of the „Moving“ Constrained localities.

Producing e.g. in an assembly cell in a production mix, we must consider also complexity of effective workplace balancing from the point of individual variants.
In experiments we are again to use computer simulation in Witness stetting (Fig. 2). We are to employ the above mentioned model exp. No. 1 p phase 3 - see chap. 1.3. In the first phase of experiments within product batch releases (Part_A, Part_B, Part_C) we are to reveal the constrained localities for individual products.

Second phase of experiment should point to the problem of „moving“constrained localities in production mix. As a key marker of process effectiveness so called Makespan (all orders complete time) will be used, applied at test functions distribution problems [4].
In the last third phase we are to concentrate on possibilities of production compromise in sequences inspired by nivellized production of Heijunka.

2.1 Simulation – Production Batch system Experiment

This system of product release into the system summarizes total quantities of orders for products (Part_A, Part_B, Part_C) for a given period. Total quantity of a required type of product is than released into the process within one production batch within a particular time interval planning period). Customer's request is then satisfied from a pre-produced stock.
Within strategies working with One Piece Flow it is possible indicate constrained localities with help of workplace statistics (Machine). Workplace preceding constrained localities is blocked – waiting for a slower machine or an operator (Fig. 3´).

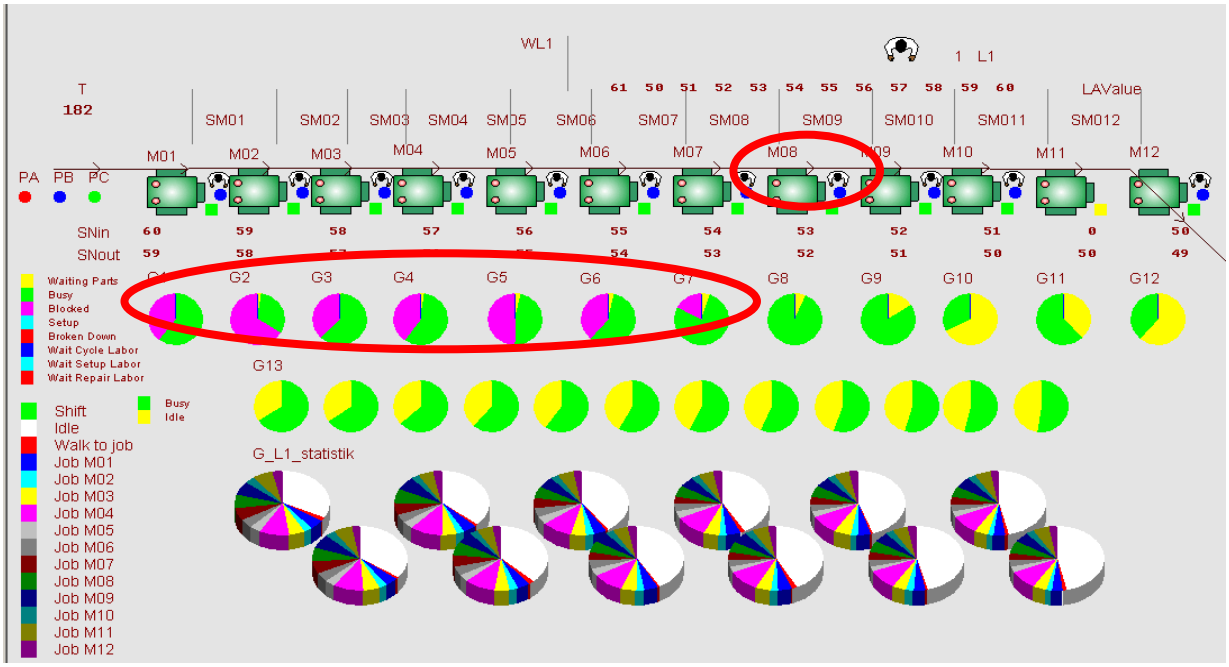

Figure 2 *Witness – OPF Caravans (Constraints in operation 8 for Part_B)*

Yet from the capacity calculations we can obtain appropriate CL (Chart 1). Generally it is not necessary to look for a constrained localities by simulation based on workplace and operators workload statistics.

From the above mentioned data outputs (Fig. 2 or Table 8 or Chart 1) we receive information about constrained locality location. Part _A corresponds to operation No. 11, for Part_B it is operating No. 8 and for Part_C it is operating No. 6.

For all described experiments we consider these time cycles, see Table 8

In this phase we are again to create a comparison base for the following steps. As a main affectivity marker we are to use Makespan (all orders complete time). Optimalisation is

thus mode of this marker minimization. The fixed parameter is the quantity of produced pieces in a final configuration: Part_A 250ks, Part_B 150 pcs and Part_C 100 pieces.

Table 9 Makespan – Time for ended all Job (Part_A, Part_B, Part_C), Labor quantity 10

Makespan to 250 Part_A and 150 Part_B and 100 Part_C		
Labor quantity 10 OPF Caravans		
LONG SEQUENCE 250/150/100	1727	100%

Based on the results of experiment No. 2, phase 1 (Table 9) creating Makespan 1727 comparison base 100%.

EXPERIMENTS NO.2 PHASE 2. – PRODUCTION MIX

JIS system - Just in Sequence arises from the JIT production strategy Just in Time. JIS of course stresses the right item sequence. The items are released into the process upon particular customer orders (external or internal). Production is thus executed in the production mix.

Different demandingess of individual variants in the mix might thus develop in a „Moving“ constrained locality. Influences thus have e.g. individual differences in time cycles not only within the process but also at the individual product variants (see Table 8 a Chart 1), relative sequence of parts, and proportional representation of products in the mix etc.

Operation	Part_A	Part_B	Part_C
1	1:53	1:53	1:53
2	1:53	0:59	0:59
3	1:15	1:58	3:16
4	1:10	1:52	3:03
5	1:32	1:32	3:32
6	1:28	1:56	4:15
7	1:16	2:41	3:37
8	1:38	3:18	3:26
9	1:19	3:02	2:53
10	1:12	1:12	1:12
11	2:18	2:18	2:18
12	1:28	1:28	1:28

Table 8 Operation cycle time

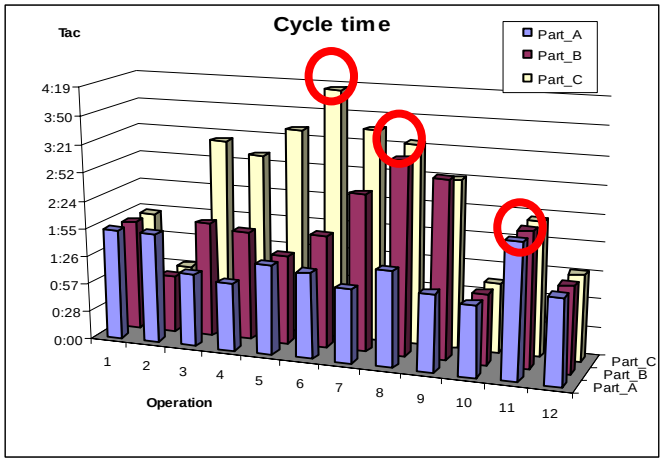

Chart 1. Operation cycle time – Constraints (Part_A, Part_B, Part_C)

Generally we can state that production mix increases the number of collision situations and to productivity decrease within the strategies based on One piece flow.

Table 10 Makespan – Time for ended all Job (Part_A, Part_B, Part_C), Labor quantity 10

Makespan to 250 Part_A and 150 Part_B and 100 Part_C		
Labor quantity 10 OPF Caravans		
MIX PERCENTAGE 50%/30%/20%	2075	120.2 %
LONG SEQUENCE 250/150/100	1727	100.0 %

The he second phase of experiment with particular production data shows increasing time demand by approx. 20.2 % while transferring to the production mix from the large sequence production. At strategies based on OPF we may thus with application of sequences

eliminate collisions o variants ad decrease time necessary or finishing all production orders and that on the level of 15%.

2.3 Experiment No. 2 phase 3. – Nivellized Production in Short Sequences

Permanently growing number of product variants and competitors fight for customer often makes production large sequences impossible. Manufacturing in production mix based on customers` orders is not effective see experiments 2nd phase, experiment No. 2.Thus in the 3rd phase we are to concentrate on affectivity of smaller sequences corresponding to the size of the process. In our particular case of process with 12 operations we apply sequence in a range (12-25 parts of the same variant in sequence).In order to retain conditions of individual variants same as in previous phases and simultaneously to reach the requested sequence extent we use Heijunka's observation on nivellised production. For this experiment we use he sequence 25Ks Part_A, 15Ks Part_B 10Ks Part_C.

Table 11 Makespan – Time for ended all Job (Part_A, Part_B, Part_C), Labor quantity 10

Makespan to 250 Part_A and 150 Part_B and 100 Part_C		
Labor quantity 10 OPF Caravans		
MIX PERCENTAGE 50%/30%/20%	2075	120.2 %
LONG SEQUENCE 250/150/100	1727	100.0 %
SHORT SEQUENCE 25/15/10	1730	100.1 %

Results 3rd step of the experiment No.2 show that yet small sequences of individual variants make it possible to reach similar results with long sequences.

2.4 Outcome of this Experiment

In the present time of current crises, yet we can recommend in aim for more effective production to focus attention also to the production nivellization. Applying small sequence production we decrease collision situations (blocking of workplaces at the out-put and waiting at the operation in-put).Yet this measure might bring more than 10% improvement in productivity, at the minimum buffer stock increase. With full implementation of Hejunka system also make full use of capacity of the related resources and suppliers.

3. CONCLUSION

Stochastic effects in any form are generally undesirable. Workers distribution strategies One piece flow – Caravans, is in principle very vulnerable to stochastic effects. Its application is within alternative strategies suitable under specific conditions. This strategy is especially demanding not only the stability of the team on a high skill level, quality operation levelling and stable process as such but also set high requirements on Multi-skill workers.
Positive aspects of this strategy are simple organization and prompt reaction to the change of production tact in process. Main profit of this strategy is minimal work-in-process direct to its principle. Strategy logics is in the same time easy to operator's understanding and can be summarized by one clause: „ An operator handles a semi finished-item and executes gradually all operations within a fabrication process, after finishing returns back to the beginning of the process for a another semi finished-item to be processed.“

Reviewer: Prof. Ing. Přemysl Pokorný, CSc.

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