Production Leveling (Heijunka) Implementation in a Batch Production System: A Case Study

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Abstract. This paper presents a case study of an implementation of a new method for Production Leveling designed for batch production. It includes prioritizing criteria of products and level production plan. Moreover, it was applied on a subsidiary of a multinational enterprise located on Brazil, which manufacturing processes comprise batch production in a make-to-stock policy. Regarding a qualitative assessment, evidences show that the company had deficient practices related to Operations Planning. Thus, based on a case study approach, proposed method was applied as well empirical data were analyzed. Results were measured before and after this implementation by performance indicators of Costs (inventory), Speed (lead time), Mix flexibility (monthly set up operations) and Reliability (service level). Evidences confirm improvements in operational efficiency as expected. Researchers and practitioners can evaluate general applicability of this method by applying it in different companies that share similarities related to batch processing operations.

Keywords: Batch Production, Heijunka, Operational Efficiency, Production Leveling.

1 Introduction

Nowadays international markets feature keen competition among both established and emerging companies that operate at global value networks. For this reason, enterprises must redesign existing methods for Operations Planning (OP). Such decision becomes more complex as product variation increases. Moreover, researchers advocate that Production Leveling – a Lean Manufacturing concept for OP – enables basic conditions to minimize the Bullwhip Effect, a dynamic phenomenon that *amplifies* and transmits the variability of customers´ demand across a supply network [8], [9], [10]. Indeed, Production Leveling improves operational efficiency by means of flexibility, cost and service level [1], [9].

Production Leveling aims to achieve a much more stable schedule for mixed-model production, by combining two well known concepts of Lean Manufacturing: Kanban System and Heijunka. The former means pull signaling of production based on concept for replenishment of supermarket to control work-in-process inventory. The latter means a smother pattern for daily production sequencing at assembling lines [7], [8], [9].

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In spite of well known relevance of such concepts, recent research evidences a sparse number of cases of implementation of Production Leveling outside automotive networks. Additionally, one can question whether Lean Manufacturing concepts can be generally applicable [5]. Hence, three main gaps of literature review can also be used to support such statement. Beginning with conceptual models focused on problem solving of mixed model assembling lines [2]. Secondly, it can be said that batch production is very suitable to a wide variety of manufacturing processes, even in an automotive supply network [3]. Finally, regarding that Production Leveling is often described as simple models and examples [8], [9] there w no particular method based on Production Leveling designed for batch production processes and its variations related to many supply networks [1].

Based on those exposed gaps, the purpose of this paper is to present a case study of a new method for Production Leveling implementation in batch production system. A case study is a good opportunity to test emergent theories aiming to validate them empirically [4]. Additionally, this qualitative research was done in early 2008 in a large company, located on state of São Paulo, Brazil [1]. Hence, this paper is structured as follows. In section 2, a literature review of the main concepts is presented, including the framework for implement Level Production as well its main activities. In section 3, research methodology is briefly explained. Section 4 comprises a case study, before and after implementation. Results of the implementation of this method are commented in the section 5. This paper ends with conclusions in section 6.

2 Literature Review

This section summarizes the main activities of the new method [1] designed particularly to level the production of batch manufacturing systems. Additionally, it is expected to suit in a wide variety of value networks. That is, aiming to explain the general applicability of this method, a classification of batch production processes was briefly explained (see Appendix A). Hence, those elements were combined into a proposed framework, as showed in section 4.

2.1 Activities Related to Production Leveling

This section briefly explains the new method that was applied for the first time on case study and it includes the following activities [1]:

- Monthly Planned Demand: comprises the first activity of Tactical Level and is based on inventory data, bill of materials and customers´ ordering book, materials planners must set, for every product model, its planned volume for the next month. After that, the Level Production Plan is a decision that starts with monthly planned demand and means the design of a leveled production pattern taking into account production mix, production batch size, set up time and a planning interval that can be set as six or more days [1], [6]. Required capacity named as total lot processing time (´production pitch´ or ´pitch´) is also calculated for every product model. That is, it comprises a better balance between both required and available capacity of process and also provides inputs to two important activities: Supermarket sizing and Load-capacity analysis. The former is related to materials and the latter comprises decisions concerning direct and indirect labor and overhead.

- Daily order entering: named as Operational Level and contains five activities of production control: loading, sequencing, scheduling, dispatching and control. In such activities, visual controls are set to improve visibility for Production personnel, such as operators and supervisors. This activity features Kanban Board, Electronic Kanban, Heijunka Board and Production Rate Control Board [1].

It is worth highlighting that the implementation of Production Leveling starts with product prioritization that usually recommends make-to-stock production must be focused on high volume ('A' items") and medium volume ('B' items) whereas make-to-order production is better suitable for low volume ('C' items) [9].

3 Research Methodology

Based on objectives of this paper, the methodological approach comprises a qualitative research that was done in early 2008 [1] by using appropriate roadmap for case studies [4]. To accomplish this work, author visited the studied company from December´07 to June´08. Hence it was divided into two phases. The first one, named 'Previous State' comprises the scenario before implementation of the new method. Secondly, 'Future State' means the condition after the implementation. Regarding those criteria, the Previous State of the company was analyzed and evidences emphasize the need for change in OPC practices. During the first month, data was gathered from direct observations, interviews, archives analysis and corporate presentations. The next month comprised a seminar for training was presented to managers, supervisors, planners and process engineers. Finally the method was applied on February´08 as well visual controls and an electronic kanban. Such operational tools will be presented in a future paper. Hence, data were gathered and results were analyzed including October´07 to December´07 and March´08 to May´08. Such work is briefly described as follows.

4 A Case Study of an Implementation

4.1 Company "A" at Previous State

The researched company, hereinafter named Company "A", is a subsidiary of a North American multinational enterprise located on Brazil. There are three industrial facilities on state of São Paulo which its manufacturing systems produce a wide variety of products for many industrial applications. However, only one facility was studied which value chain is described as a make-to-stock batch production system which parts processing are typically disjunctive operations (See appendix A).

4.1.1 Features of Products and Pacemaker Process

Due company policy for information confidentiality, it was necessary to change the name and the type of manufacturing processes as well its products types. Additionally, the last productive stage, focus of this paper, is similar to a stamping press process and comprises two identical machines that convert different types of hot rolled steel coils into up to 130 product models. At downstream side, there is an automatic packing machine that operates in two steps. First, parts are grouped into 200 units each and secondly there is a non automated palletizing machine to group 250 packages in a single pallet. In this Previous State, there was no problem concerning neither packing process nor standard packages.

Based on Lean Manufacturing concept, the daily production schedule was generated by scheduling software and daily schedules reports were sent only for both press machines. That is why such productive stage can also be named as the 'pacemaker process' because they set the production pace of upstream processes. Both press machines run at three shifts a day and six days a week. Furthermore, every day has 3 breaks for shift which comprises 10 min for shift reporting and 1 hour for lunch each. Moreover both machines have 98% of average Uptime, each of them can be operated 20.25 hours a day, from Mondays to Fridays; and 15 hours on Saturdays.

4.1.2 Problems Concerning the 'Previous State'

Based on previous analyses of gathered data from interviews, direct observation and archives analyzing, the new method was proposed because there was no strategy for continuous improvement. Evidences revealed that company had many operational problems such as uneven pattern of daily production related to overproduction using big-sized production batches related to three or four hot rolled steel coils at once. Additionally, there were no visual controls as well a huge amount of finished goods inventory and a non suitable condition for using kanban cards for pull system triggering. Finally, there was neither prioritization of products nor a consistent inventory reduction plan [1].

4.2 'Future State' Planning

Based on presented framework, a Level Production Plan must be set to provide a further analysis of available capacity. Those decisions are summarized as follows.

4.2.1 Prioritization of Products ('A' and 'B' Items)

The proposed method includes the criterion for classification of products based on monthly demand, namely 'ABC analysis' previously explained. By using it, it was found that among up to 130 product models, only 22 items correspond to 80% of average demand in value. So, the Production Leveling can be applied to be focused in a few items. After that, instead of running all products in both machines, 22 items were divided in two groups of 11 items each and one group was set for each machine. Remaining 108 low volume items corresponds to 20% of monthly average demand shall be produced once a month in both machines.

4.2.2 Production Leveling Planning

After the previously explained activity, a Level Production Plan was designed to both machines. Operations Planner has set a monthly planned demand for every product model as the average of the last three months and the next two forecasted monthly demand. After the training seminar, manager and supervisors decided that the Level Production Plan should be set as a six days week for time horizon. Such decision was made to provide a direct connection between planning interval and normal working time interval.

After selecting prioritized items, project team designed a Level Production Plan for both machines by leveling the required capacity using three information types: Set up time, production lot size and production rate at the pacemaker process. For both machines, average set up time was equal to nine minutes for every product model. Batch sizes were set as the minimum possible value related to the length of one single hot rolled steel coil. This criterion diverges on previous condition of ´Previous State´ and each product model has a different ´minimum-size lot' due differences in length in hot rolled steel coils. Thus, based on results, managers stated it was a great contribution of the method. Finally, production rate comprises the pace that machines are able to produce parts per unit of time (parts per minute). For its turn, production rate also vary as product model does, for instance, for a generically named Model ´E´ it is equal to 417 parts per minute.

The first decision features a calculation of production cycle within a given interval. That is a relation between average monthly demand and production lot size. By dividing the former by the latter, it defines a theoretical number of monthly set up operations. Second decision includes calculating the required capacity ('production pitch' or 'pitch') for each product model. In other words, is necessary to evaluate the total processing time elapsed from setting up machine till concluding a complete lot for a given product model. At last, the level production plan gives a visual distribution as shown in Fig. 1 as follows.

Product Model	Mon	Pitch (min)	Tue	Pitch (min)	Wed	Pitch (min)	Thu	Pitch (min)	Fri	Pitch (min)	Sat	Pitch (min)
J	84,000	177			84,000	177			84,000	177		
E	69,300	175			69,300	175	69,300	175			69,300	175
A	69,300	148			69,300	148			69,300	148		
C	63,000	135					63,000	135				
S											105,000	189
L									150,000	219		
M			105,000	219								
B											94,500	198
U			63,000	198								
D						52,500	114					
V			25,200	85								
Daily Required Capacity (min)		635		502		500		424		544		562
Daily Available Time (min)		1,215		1,215		1,215		1,215		1,215		900
Daily Remaining Time (min)		580		713		715		791		671		338
Utilization of Capacity (%)		52%		41%		41%		35%		45%		62%
Daily Number of Set up		4		3		3		3		3		3

Fig. 1. Level Production Plan for Machine #2 with six days of time horizon

Fig. 1 depicts a Level Production Plan with six days of planning time interval. First left column has selected product model grouped in Machine #2 whereas every week day has production batches (columns labeled as days of week) and its related required capacity in minutes (´Pitch´). On bottom left side there are five rows namely 'Daily Required Capacity' is the sum of daily production pitch. For its turn 'Daily Available Time' is the normal daily available working time. Moreover, ´Daily Remaining Time´ is the difference between the first two previous rows and ´Utilization of Capacity´ is set as ´Required Time´ divided by ´Available Time´. Finally, ´Daily Number of Set up´ is the result of leveling of required capacity of high volume items within planning interval, aiming to get an even pattern for production schedule in terms of daily utilization of capacity. Furthermore, Fig. 1 also depicts that utilization of capacity was set varying from 35% to 62% for 'A' and 'B' items which implies an opportunity to review actual normal working time. Finally, this level production plan enabled team to decrease production lot size to as small as possible to a minimum value. After implementing this method, due high mix variety, team members developed an electronic Kanban by combining four key elements: an inventory management system based on 'Reorder Point' or 'Fixed Quantity' model (logical feature), bar codes and bar code readers for production back flushing (data input), an inventory system managed by a MRP software (data base) and an electronic spreadsheet combined with Visual BasicTM routines for data transferring (data output). Such tool as well new visual controls have improved Operational practices.

5 Research Findings

Results were analyzed in terms of performance indicators of Mix Flexibility (number of monthly Set up), Costs (inventory), Speed (days of stock) and Reliability (service level). Data was gathered and divided into two intervals: three months before the implementation ('Previous State') and three months after the implementation ('Future State'), as shown in Fig. 2 as follows:

PERFORMANCE INDICATORS	OBJECTIVE	PREVIOUS STATE				FUTURE STATE				VARIATION (%)
		Oct/07	Nov/07	Dec/07	AVERAGE	Mar/08	Apr/08	May/08	AVERAGE	
MONTHLY DEMAND (THOUSANDS OF PARTS)	REVENUE	11,086	11,702	11,883	**11,5571**	13,357	9,914	10,617	**11,2959**	-2%
PLANNED INVENTORY (THOUSANDS OF PARTS)	COST	4,447	4,694	3,991	**4,3774**	5,196	5,289	5,923	**5,4691**	25%
ACTUAL INVENTORY (THOUSANDS OF PARTS)	COST	5,118	3,868	3,925	**4,3035**	3,368	3,421	3,195	**3,3282**	-23%
ACTUAL INVENTORY (DAYS OF STOCK)	SPEED	14.1	9.3	9.9	**11.1**	8.4	8.4	8.7	**8.5**	-23%
AVERAGE LOT SIZE (PARTS)	FLEXIBILITY	72,207	70,008	73,087	**71,767**	57,626	66,962	51,710	**58,766**	-18%
MONTHLY SET UP (SET UP PER MONTH)	FLEXIBILITY	173	158	168	**166.3**	200	178	171	**183.0**	10%
SERVICE LEVEL (%)	RELIABILITY	99.6	99.1	98.9	**99.20**	98.0	98.4	99.0	**98.46**	-1%

Fig. 2. Summary of total achieved results regarding 'A' and 'B' items

Fig. 2 shows that even on a steady average monthly demand, production planner increased planned inventory in 25% regarding demand forecasting. However, results evidence that actual inventory decreased in 23% in average monthly values after proposed method. Also, 'days of stock' decreased at the same rate as expected. By setting lot size as a minimum possible value fig. 2 shows that average lot size has also been decreased by 18% in monthly average value. This evidences that the number of monthly set up has also increased in 10%. Indeed it is worth stating that results could be better for smaller lot sizes. Finally, service level has not been changed indicating that there was no negative effects in this case.

6 Conclusions

After analyzing ‘Previous State’, data evidence that company should improve existing methods for Operations Planning regarding Lean Manufacturing principles. The ‘Future State’ began with changes at ´Tactical Level´ and monthly planned demand was set as well a Level Production Plan. By leveling the required capacity of both ‘A’ and ‘B’ items, team members were able to set a minimum size criterion for production batches. Indeed, utilization of capacity now varies from 35% to 62% with implies an opportunity to evaluate changes in normal working time. Based on that, findings evidence that method leaded to improvements in operational efficiency. Thus proposed method was accepted by top and middle management as well Production personnel. Additionally, visual controls and electronic Kanban were also implemented but such tools will be presented in a future paper. Finally, based on research limitations, researchers and practitioners can review these concepts aiming to test its general applicability in different batch production systems in make-to-stock policy with high product mix variety.

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Appendix A: Classification of Batch Processing Operations

Production Leveling is expected to be generally applicable in batch production systems featuring processing operations [1] as described as follows:

- Disjunctive type I – Processing operation that converts a single piece of material into several ones. For instance, a press stamping like process that transform hot rolled steel coils to generate multiple purpose parts.
- Disjunctive type II – Processes that convert either powders or pellets into a batch of parts such as extruder machine as well sintering and injection molding.